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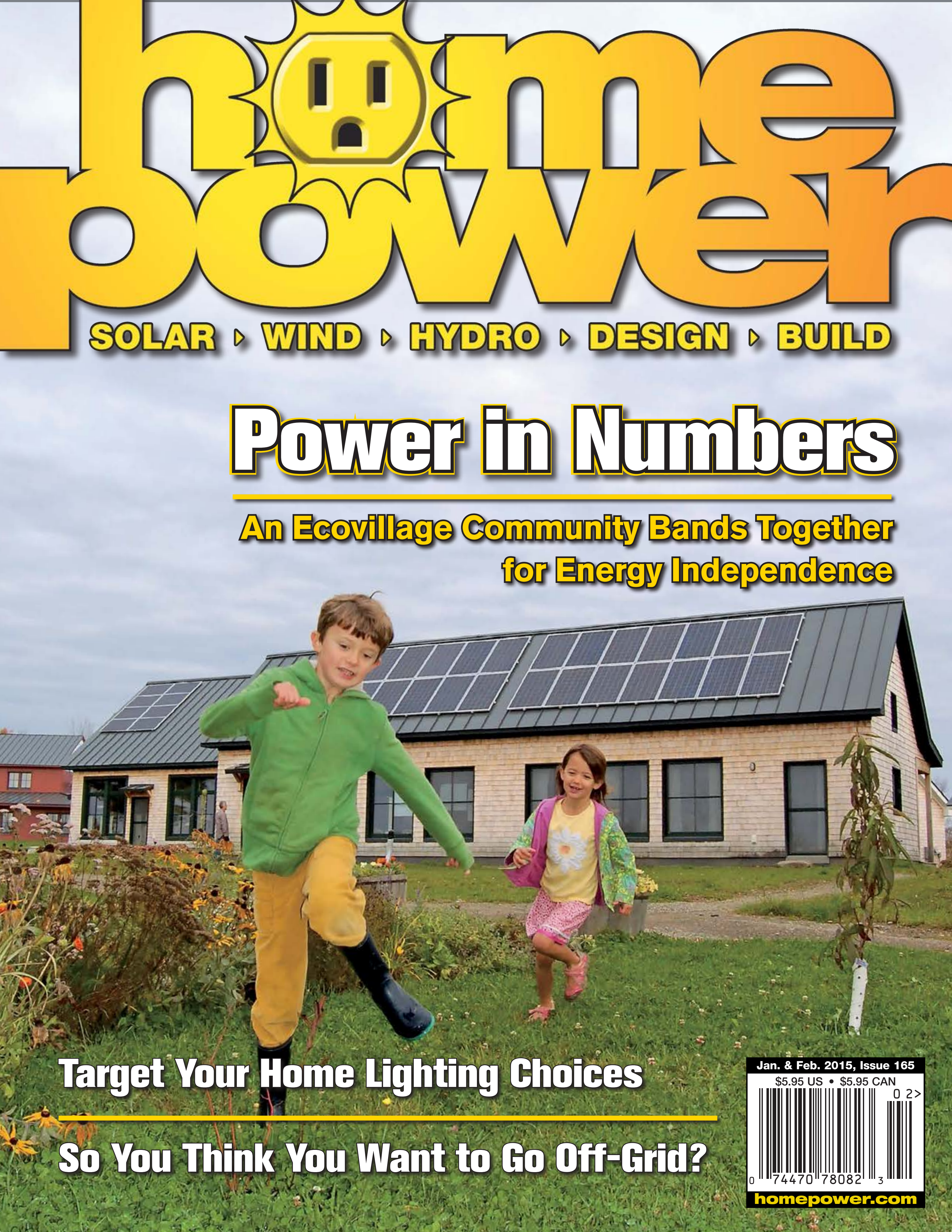

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On the Cover

Children frolic in front of solar-powered homes at the Belfast Cohousing & Ecovillage community in Maine.

Photo by Steve Chiasson

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january & february 2015

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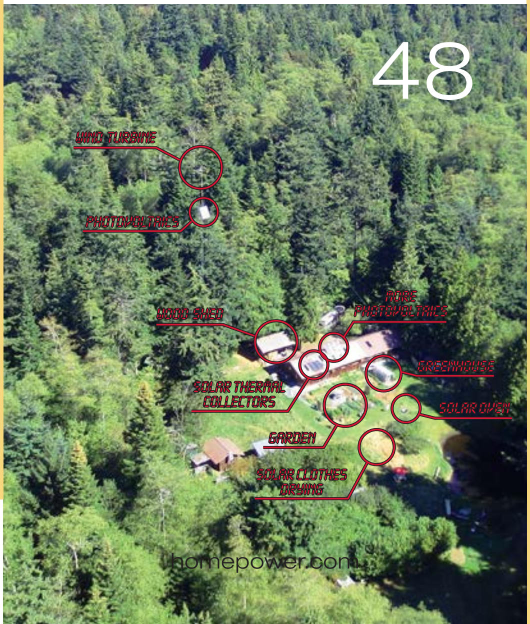

In Back

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Celebrating *Home Power* Cofounder Karen Perez

Courtesy Richard Perez

With great emotion, from the deepest sadness to the most heartfelt appreciation, the *Home Power* crew shares the passing of our dear friend, coworker, and cofounder Karen Perez. Karen was diagnosed with cancer in fall 2013. With her husband Richard at her side, as well as family and friends, she passed away on November 7, 2014, among the swirling of sweet stories, thoughts, laughter, and quiet reflection.

Karen's journey started in St. Bernard Parish, Louisiana, in 1949. In her late teens, she headed west to be part of the cultural awakening that was San Francisco in 1968. In The Haight, a center of that turmoil and celebration, she met her future husband, Richard Perez. In 1970, Karen headed north—this time with Richard and a group of friends—to homestead a piece of property in a remote corner of southwestern Oregon called Agate Flat.

The early days on the Flat were hardscrabble. Shelter was built with hand tools. Food was packed in on horseback. Lighting was rigged from salvaged automotive lights and batteries—and eventually from the 48-watt PV module that sparked the vision that would grow into *Home Power*. With the help of friends, old and new, the magazine's early community of readers, and the first Macintosh computer, Karen and Richard founded *Home Power*, "The Hands-On Journal of Home-Made Power," in 1987.

For close to 30 years, Karen worked both on the front lines and behind the scenes at *Home Power*—walking step by step with Richard down the long path of creating a clean energy future and a healthier environment. In that time, she saw solar energy grow from a niche technology that helped off-grid folks live more sustainably beyond the reach of the power lines to one of the fastest-growing sources of energy on the planet.

Karen loved a lot with steadfast dedication and affection, and her courage and compassion extended to caring for all creatures furry, fluffy, or feathered. Be it a dog, cat, bird, horse, mule, or even the potbellied pig that showed up one day and set up shop under the cabin (Tilly, as she came to be called, was pregnant, of course), Karen was a champion of all critters, great and small.

If you're so inspired and would like to make a charitable contribution in Karen's name to keep her vision moving forward, we suggest the Solar Electric Light Fund (self.org) and the ASPCA (aspca.org). The Solar Electric Light Fund's mission is to design and implement solar energy solutions to assist the 1.5 billion people living in energy poverty. The ASPCA operates in various program areas, including anticruelty, animal health services, and community outreach.

Fare you well, KP. We love you.

—The *Home Power* crew

Think About It...

"Goin' home, goin' home; by the waterside I will rest my bones;
Listen to the river sing sweet songs to rock my soul."

—"Brokedown Palace," lyrics by Robert Hunter, music by Jerry Garcia, 1970

contact us

Home Power—independently published since 1987

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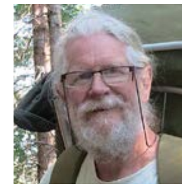
contributors

this issue's experts

Home Power Managing Editor **Claire Anderson** lives in a passive solar, (almost) net-zero-energy home she and her husband designed. She and her family are developing their 4.6-acre homestead to incorporate rainwater harvesting, graywater reuse, organic food and flower gardens, and maybe a milking goat or two.

Thirty years ago, **Kathleen Jarschke-Schultze** answered a letter from a man named Bob-O who lived in the Salmon Mountains of California. She fell in love, and has been living off-grid with him ever since. *HP1* started a correspondence that led Kathleen and Bob-O to *Home Power* magazine in its formative years, and their histories have been intertwined ever since.



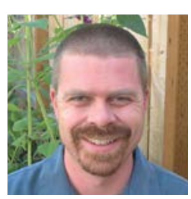
Michael Welch is a senior editor and has been with *Home Power* for 25 years. He has been an energy activist since 1978. He lives in an off-grid home in Humboldt County, California, and works out of a grid-tied, PV-powered office in Arcata.

Brad Berman writes about alternative energy cars for *The New York Times*, Reuters, and other publications. He is frequently quoted in national media outlets, such as *USA Today,* National Public Radio, and CNBC. Brad is the transportation editor at *Home Power* magazine.

Sarah Lozanova is an environmental journalist who has experience working with small-scale solar energy installations and utility-scale wind farms. She earned an MBA in sustainable management. She and her family reside at the Belfast Cohousing & Ecovillage community in midcoast Maine.

Alex Wilson is the founder of BuildingGreen, the Brattleboro, Vermont-based publisher of *Environmental Building News*, *GreenSpec*, and LEEDuser.com. He is also president of the Resilient Design Institute.

Chris Calwell is an energy-efficiency consultant in Durango, Colorado, and the cofounder of Ecos Consulting. He first worked on residential lighting efficiency for the Natural Resources Defense Council in 1989, helping utilities implement compact fluorescent bulb programs. He recently designed and built a net-zero-energy (NZE) home, and now consults independently on plug loads, lighting, NZE home design, EVs, and clean-tech investing.



Ryan Mayfield is the principal at Renewable Energy Associates, a design, consulting, and educational firm in Corvallis, Oregon, with a focus on PV systems. He also teaches an online course in conjunction with *SolarPro* magazine and HeatSpring.

Home Power senior editor **Ian Woofenden** has lived off-grid in Washington's San Juan Islands for more than 30 years, and enjoys messing with solar, wind, wood, and people power technologies. In addition to his work with the magazine, he spreads RE knowledge via workshops in Costa Rica, lecturing, teaching, and consulting with homeowners.

Author and educator **Dan Fink** has lived off the grid in the Northern Colorado mountains since 1991, 11 miles from the nearest power pole or phone line. He started installing off-grid systems in 1994, and is an IREC Certified Instructor for both PV and small wind. His company, Buckville Energy Consulting, is an accredited Continuing Education Provider for NABCEP, IREC, and ISPQ.

Justine Sanchez is *Home Power*'s principal technical editor. She's held NABCEP PV installer certification and is certified by IREC as an Affiliated Master Trainer in Photovoltaics. An instructor with Solar Energy International since 1998, Justine leads PV Design courses and develops and updates curriculum. She previously worked with the National Renewable Energy Laboratory (NREL) in the Solar Radiation Resource Assessment Division. After leaving NREL, Justine installed PV systems with EV Solar Products in Chino Valley, Arizona.

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Home Power works with a wide array of subject-matter experts and contributors. To get a message to one of them, locate their profile page in our Experts Directory at **homepower.com/experts**, then click on the Contact link.

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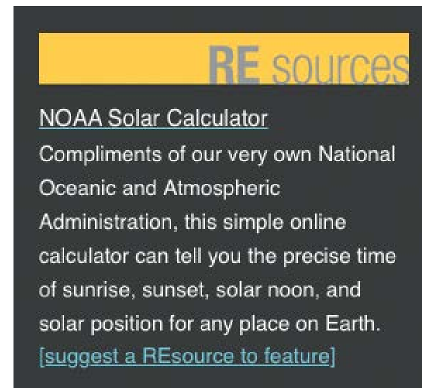


Courtesy MREA

WHEN is a Wind Turbine Tower TOO TALL?

When it comes to wind turbine tower selection, the often-repeated mantra is that "taller is better," but taller is also more expensive. So, where's the sweet spot between maximizing energy output and spending your hard-earned money? Check out our experts' replies at **homepower.com/TowerEconomics.**

Share What You Know

With the myriad ways we enable and encourage participation from our learned and faithful readership, sometimes we forget to mention the oldest and most obvious way you can participate—write an article! If you have a renewable energy story to tell or some particular expertise that you've noticed absent from *Home Power*, check out our author guidelines page for a thorough introduction to our process and preferences. **HomePower.com/authorguidelines**

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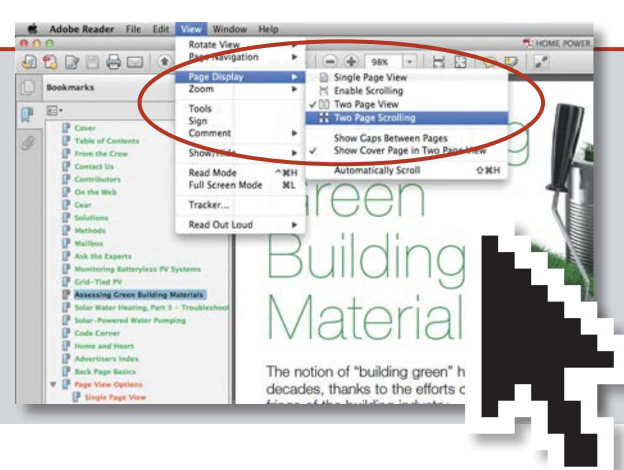

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Electric Vehicle Supply Equipment

All images courtesy of the manufacturers

EV owners can add about 20 to 25 miles of range per hour of charging with a 240-volt home charging station—officially called Level 2 electric vehicle supply equipment (EVSE). Compare this to Level 1 charging at 120 volts from a common household outlet, which only adds about three to four miles in an hour, and you'll see why an EVSE is a useful complement to your EV.

Clipper Creek HCS-40

Many experienced EV drivers put Clipper Creek chargers at the top of their list. In production for more than 15 years, the equipment isn't the most attractive, but is considered affordable and durable. It has no display or software to go wrong, is compact and has a 32-amp limit and a 25-foot cord. ($590 hardwiring or $644 for plug-ready; 3-year warranty; clippercreek.com)

AeroVironment (AV)

The slightly less revered AV charging station has about the same specs and footprint as the Clipper Creek, but a nice wraparound cord-handler. Options include a plug-ready version, a 25-foot cord, and full-service installation. ($799 to $999; 3-year warranty; evsolutions.avinc.com)

Bosch Power Max

This unit has a nice style, and is compliant with all of the major EVs on the market. It comes with an 18-foot cord; if you want it with a 25-foot cord, you'll pay about $150 more. Purchase includes a free consultation with a vehicle-charging advisor who does onsite cost estimation, then works on installation and inspection. ($593/$749; 3-year warranty; pluginnow.com)

GE WattStation Wall Mount

Attractive, but pricey, some users think it's too big or too loud. The on/off button avoids a phantom load, while other EVSEs—especially those with connectivity—continue to use energy. At 16 feet, the cord for this unit is slightly shorter than most. Make sure it reaches all the way around your electric car. (From $599; 3-year warranty; bit.ly/GEwattstation)

Electric Motor Werks' JuiceBox

The base price for the Premium Assembled Unit of this open-source EVSE is below most others, and includes a 6-foot input cable with 14-50P plug. This California-manufactured 60 A charging station includes a 25-foot cable for 32 A charging. Its open-source flexibility is built around an Arduino microcontroller, ready to adapt with special displays, Wi-Fi, remote control, or other modifications being dreamed up by the developer community. ($438 or $508 with a 60 A charger cable; 1-year warranty; emotorwerks.com)

Schneider Electric EVlink

Priced competitively while earning high marks from EV drivers, the EVlink's low profile and small size mean it takes up little room. It comes with an 18-foot cord, docking port, and cable holder. This unit is available from big box and online stores. ($599; 1.5-year warranty; schneider-electric.us)

Siemens VersiCharge

This reasonably priced 30 A charger gets high ratings from consumers. It is German-built with a high-quality finish, good cable management, and is smaller and lighter than some competing products. Its 20-foot cord is adequate, and includes a function to delay charging to utilize off-peak utility rates. The hard-wired model cannot be installed outdoors. ($699 for the universal model—plug-in; 3-year warranty; bit.ly/VersiCharge)

—Brad Berman

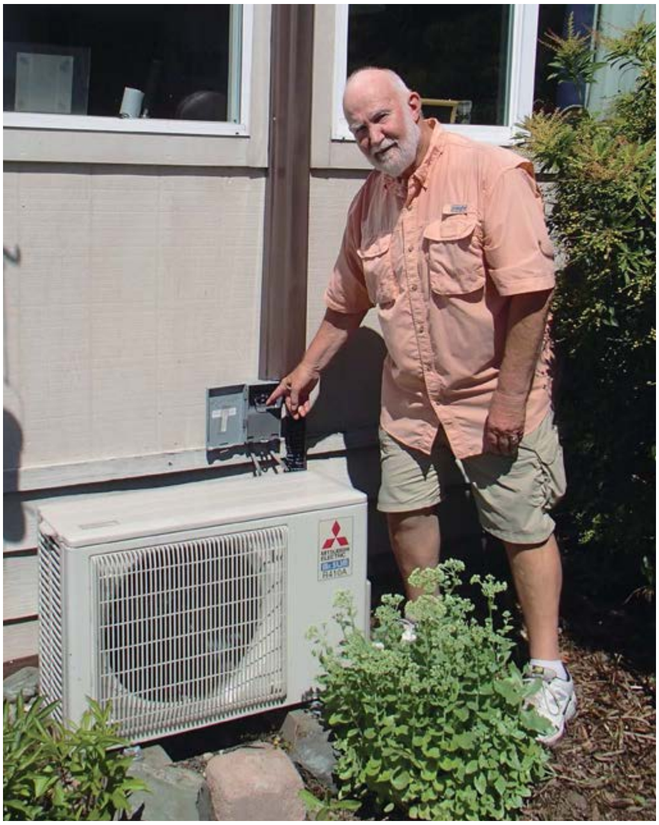
Reducing Energy Use, One Load at a Time

Owners of a decades-old manufactured home push the envelope on energy efficiency, cutting their home's electricity use by more than 70% with cost-effective upgrades.

When Glenda Alm and Dick Kent decided to put down roots after four years of traveling, they bought a 30-year-old manufactured home in a mobile home park overlooking Padilla Bay in Bayview, Washington. It got them back to their Northwest roots, and gave them a home with a great view.

But the poorly insulated, leaky home was heated with a 30-year-old electric furnace, and the previous occupant had used an average of 45 kilowatt-hours (kWh) of electricity per day. Their first task was to identify and replace any energy wasters to reduce their household consumption and electricity bill.

Homeowner Dick Kent with the upgraded heating system—a minisplit heat pump.



Ian Woofenden

Glenda and Dick were no strangers to tackling energy efficiency and living on an energy budget. They had both lived with off-grid PV systems, and four 100-watt PV modules had kept the batteries in their RV topped off while they were traveling and without shore power.

The home they bought had advantages over the neighboring mobile homes because it already had better wall insulation and windows. For starters, Dick cleaned and sealed the ducts, and added tight rodent-proof skirting all around the home.

The previous owners had upgraded the kitchen appliances about seven years before Dick and Glenda purchased the home, so they were not the worst energy hogs. They replaced the clothes washer with a new Whirlpool HE model using a utility incentive program. They still prefer solar clothes drying, and seldom use the 20-year-old electric dryer. They replaced the 20-year-old refrigerator with a new and smaller (15 cubic feet) model that uses about 400 kWh per year.

Lighting was an obvious early target—the existing lighting was 25 bulbs totaling 2,000 W. Today, 15 LED bulbs and three CFLs—a total of 320 watts—result in nearly the same lumens, and some task lighting has improved the functionality. The local utility offered LED bulbs at a deep discount, which also helped fund the improvement.

Dick removed a big and wasteful 36-inch CRT TV (300 W), and replaced it with a smaller, efficient, LCD model (100 W). Dick and Glenda only use it about 10 hours a week—which translates into about 50 kWh per year.

Next, Dick ferreted out the phantom loads that were using energy continuously—such as the entertainment center and pellet stove remote—while giving no benefit in return. Plug strips were a key part of curbing these loads, making it easy to turn off related loads with the same switch. At 30 W, the pellet heater's remote control receiver was a "large" phantom load at 263 kWh per year. Put on a plug strip, the heater is now a negligible load.

These few, easy changes, with little investment, reduced energy use by 13 kWh per day—from 45 kWh to 32 kWh. Next, they tackled the heating system. The forced-air electric furnace was a prime candidate for an energy upgrade. The Wesco furnace was 30 years old and most likely contributed to nearly 50% of the energy cost with 20-plus kWh per day. It

continued on page 18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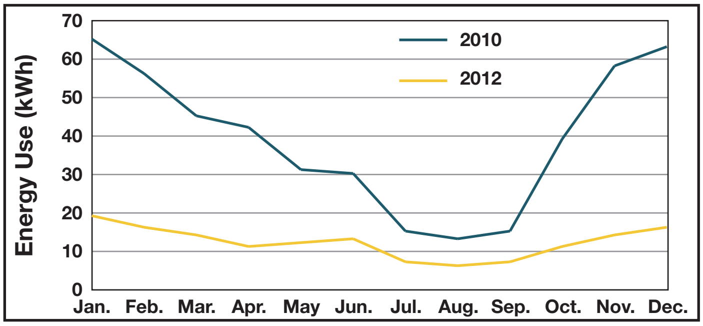
Daily Energy Comparison



was removed, and the vents all sealed permanently to eliminate energy losses. At the same time, the floor was reinsulated with R-16 fiberglass batts between the 2-by-6 floor joists.

Dick replaced the furnace with a ductless minisplit air-source heat pump purchased online for $1,500. He and a friend installed it in a few hours, but hired a local HVAC company to check for leaks and charge the system with refrigerant. With a $1,200 rebate from the local utility, the upgrade cost less than $500. The old 4 kW electric furnace used about 24 kWh per day, while the new 1.2 kW heat pump averages less than 5 kWh per day.

While working on the heating system, Dick also dealt with the old plumbing in the home. He remodeled both bathrooms, installing PEX plumbing with no fittings under the floor. He discarded the 20-year-old electric tank water heater and installed a Rheem 13 kW tankless electric water heater ($200). While the electricity draw of the on-demand heater is high, there are no standby losses as with a tank-style heater, reducing water-heating energy use by about 75%. Short plumbing runs also curb energy losses and wait time for hot water in both bathrooms and the kitchen. Dick used a manifold system—each appliance is served by a home run with no plumbing fittings under the floor (direct connection) and not a series connection from one use to the next.

The space- and water-heating efficiency upgrades reduced the household electricity use by another 20 kWh, bringing it down to about 12 kWh per day. At $0.106 per kWh, Dick and Glenda now pay about $60 per month for electricity in the winter (and buy 100% green energy from the local utility). Many of their neighbors living in all-electric homes in the park pay $300 a month for electricity in the winter.

With a couple of decades in the RE industry, it's no surprise that Dick has already installed a few PV modules—four 100-watt modules on his off-grid workshop keep a small battery bank charged to run his power tools. They are the same style of module he had on his RV and that he sold to RV clients. But Dick has bigger plans, and is considering a 2 kW batteryless grid-tied PV system, which would get their house about halfway to net-zero energy use.

—Ian Woofenden

Comment & Discuss this article @ homepower.com/165.20

Off-Grid Feasibility & Sustainable Load Shifting

With no load shifting and no generator, the author tackles the economics of taking her almost all-electric on-grid home off the grid.

When people visit our rural house for the first time and see the roof-mounted PV array—52 modules covering most of the south-facing rooftop—they often assume that we're off-grid. Nothing could be further from reality—in fact, all but one of our household loads are supplied by electricity, which would be highly unusual for an off-grid house. The exception is space heating, which is normally provided by direct solar gain and a small, efficient wood heater.

I often find myself explaining why we chose a grid-tied PV system—how, even though we have a multitude of electrical loads, our system capitalizes on the utility's net metering program and offsets nearly 100% of our electricity use annually. Then I explain how much an off-grid system would cost to meet our home's loads—especially in winter, when it may be necessary to supplement our passive solar gain with electric heat, but sun-hours dwindle. Without any load shifting (using a non-electric energy source for a task, such as propane refrigeration) or generator use, an off-grid PV system would be ridiculously large, complex, and come with a similarly ridiculous price tag.

Nerding on the Numbers

Just how big? My son and I took an afternoon to record, measure, and estimate every wintertime household load—down to the LED nightlight in the master bath. Even though we rarely use it, we also included the estimated energy use of our backup hydronic heating system, which is served by a 30-gallon electric water heater. (We almost exclusively use our wood heater for space heating, but I wanted this exercise to reflect taking an all-electric, "efficient" home off the grid.) We calculated an average daily winter electrical load of approximately 48 kilowatt-hours (kWh).

Generating that detailed list was time-consuming enough, so I turned to AltE Store's online off-grid system calculator (bit.ly/altEcalculator) to estimate how much the system might cost. I didn't get into the complexity of sizing for surge loads of various appliances, which was beyond the scope of this exercise, but those need to be considered to size the inverters.

I sized the system for only two days of autonomy (i.e., relying strictly on the battery bank), which would mean extreme load shedding measures or dependence on a backup generator during longer periods of cloudy weather. According to their calculator, we'd need:

- 32.84 kW of PV modules. Cost: $32,550.

If we used 315-watt SolarWorld modules, that means we'd need about 105 of them. At 39 by 78 inches each, we'd need 2,218 square feet to accommodate them. The south-facing roof on our house is about half that size, so we'd also need to consider a ground-mounted system or build a very big barn with a very big roof. It's important to note that location plays a prime role in the system's size. For example, if we lived in Boulder, Colorado, we could get by with an array that is 54% smaller—48 modules instead of 105.

- Depending on the system's configuration, we'd also need five OutBack Power Radian 8,000 W inverters. Cost: $22,587
- The 48 V battery bank would consist of about 72 Surrette flooded lead-acid batteries; 2 V, 1,765 Ah at the 20-hour rate. Cost: $67,800.

We'd need to build a power shed to house this equipment or dedicate a room in the new barn we'd need to build—adding more cost to the project.

- We'd also need nine charge controllers for the huge battery system. Cost: $4,990
- Total for modules, inverters, controllers, and batteries: About $128,000—without shipping.

To fund just the basic equipment cost, we'd need very deep pockets indeed. Keep in mind that this is the bare-bones price; I haven't included mounts, combiner boxes, circuit breakers, wiring, mains panel, nor labor costs, which would add thousands more.

Revisiting Load Shifting

Unless we win the lottery, an off-grid system would definitely be out of reach for us without some serious load shifting (see "Shifting Loads Renewably" table). Some loads are obvious and easier to shift in a more sustainable way (i.e., without resorting to fossil fuels). For instance, on sunny winter days, we can use our portable solar oven to bake instead of an electric oven, and hang clothes on a line to dry outside. When the rain hits, though, we'd be out of luck on both counts, and would need to shift loads away from electric. For example, we could use a wood cookstove for baking and line-dry our clothes indoors.

Shifting Loads Renewably

Existing Load	Shift To	Energy Source	Replacement Cost (Est.)	Daily kWh Offset
Electric clothes dryer	Clothesline & indoor drying racks	Passive solar	100	1.66
Electric cooktop & electric oven	Wood cookstove	Firewood	$2,600	5.76
Water heating	Solar heating system**	Solar	$10,000***	13.28
Hydronic space heating	Wood heater	Firewood	$2,000*	13.11
	Solar collectors	Solar	$4,500	
		Totals	$14,700*	33.81

*Wood heat option selected vs. solar collectors for space heating
**Two 40 sq. ft. flat-plate collectors with 80 gal. storage
***SWH = $7,500 plus heat exchanger retrofit to new wood heater $2,500

The most difficult load for us to meet and still be "sustainable" would be water heating, since cloud cover can be long-lasting here during the winter and solar water heating collectors will work only moderately well. Marrying the solar collector piping to a hydronic loop(s) in a wood heater could be a renewable solution, albeit somewhat complicated, as we'd have to retrofit our existing wood heater or replace it.

The consequences of this load shifting would be substantial: a reduction in our electrical loads to about 14 kWh, which would be a daily savings of about 34 kWh.

Load-Shifting Details

Load-shifting to another sustainable source can be complex and more costly than just load-shifting to fossil fuels, but it brings up an important point: Many people idealize severing their ties to the electrical utility to get "off the grid," not realizing that they will have to increase their reliance on other "grids"—the mining and fracking operations that provide the propane to fuel water heaters or a cooking range; or the mining and transport of diesel, gasoline, or propane to fuel a backup generator; or the mining, refining, and transport of gasoline to fuel their cars, since they'll need to drive farther and perhaps more often to get to town.

Although wood is technically a renewable resource, even the cleanest-burning wood heater contributes particulates to the air, adding to localized air pollution. One of the keys to heating more sustainably with wood is dispersion, so load-shifting to wood heat should only be done in rural areas that are less populous.

The lesson: When you're off-grid, it's usually far less expensive to load-shift than to try to serve heating loads with PV-made electricity. An additional investment in appliances and systems for load-shifting ($14,700) reduces the off-grid system equipment costs to about $45,000—together, only about one-third of the cost of the originally designed system (9.58 kW: 31 modules vs. 105; 24 instead of 72 batteries).

—Claire Anderson

Courtesy Russ Mueller

Solar Road Kill

A few months back, I saw this bottle embedded in a PV module while driving back to Taos, New Mexico, from Albuquerque. More recently, on another trip to Albuquerque, I made a point of stopping. Sure enough, the module hadn't been replaced yet and the bottle was still there. The array is on the post of a large road sign, part of a solar lighting system, just north of Santa Fe on highway 84/285. The modules are about 12 feet off the ground. I imagine it was some sort of hooligan who made the shot from a car window.

Russ Mueller • Buffalo Solar

While I'm dismayed by the hooliganism and litter, it is no surprise that we see things like this as PV becomes more common. I have long said that one of the signs of the success of solar technology will be "road-kill PV"—PVs strewn on highway shoulders (along with fan belts, tire treads, and bungee cords), a result of their accidental relocation from their perch on RVs, trailers, and such.

While this module will need to be replaced, the reality is that it was indeed a fluke that yielded this result, since PVs are very tough. The photo also has an artistic quality to me, and perhaps will inspire use of cast-off, retired, or purchased modules in new ways, as PV becomes normal and ubiquitous in our culture.

Ian Woofenden • Home Power *senior editor*

Wind Physics

I enjoyed David Laino's article on wind physics ("Wind Energy Physics" in *HP161*). It has excellent, usable, and applicable physics information that dispels a lot of common mistakes that the inexperienced would make.

I'm a 69-year-old solar enthusiast who's been into solar since the early 1970s (mostly PV and hot water systems—my latest project is eight solar hot water collectors to heat my greenhouse). My first wind generator attempt would have been to build a funnel for more air through the machine. Multi-bladed machines came to mind, followed by different designs such as some of the illustrations you provided—all mistakes you helped me avoid! Thanks for helping me and others see the errors of our thoughts.

I've gotten some bad information in the past, and it just cost me a lot of time and money. I want to compliment you on a well-written article—clear, concise, precise.

Don Tollefson • Venice, California

Insuring a Ground Mount

After living off-grid for 25 years in northern New Hampshire with a North Wind HR2 wind generator, wood heat, and solar hot water, my wife and I backslid into on-grid life for 15 years (other than continued use of wood heat). We "found our way" again in the summer of 2014 when our vintage BMW motorcycle restoration shop installed a grid-tied PV array.

The system is 40 ET Solar 250-watt modules with microinverters on two Schletter ground-mount racks. Calculations suggested that the two arrays will provide 100% of the electricity needed for our business. The system will also create an income stream through the New Hampshire Public Utilities Commission's renewable portfolio standard, which pays $0.05537 per kWh produced. This will be adequate to pay for most, if not all, of our residential electrical consumption.

The system went online in July 2014, and we were elated with its production and our re-entry into the wonderful world of renewable energy. But then it appeared that we might be unable to insure our arrays.

We approached five different insurance agencies, one of which has provided our home, motor vehicle, shop building, and business liability insurance for 15 years. Two agencies did mention casually that they could provide "surplus line" insurance at a cost of more than $1,000 per year!

Explanations given by the insurance agencies were that the arrays were not insurable because they were business related; they were motorcycle business related; they were ground-mounted; or any combination of the aforementioned. It seemed, however, that the real problem was the insurance companies' lack of knowledge about PV systems.

Our system installer had recommended a local insurance agency that had worked with him on other projects over the past decade, so we contacted them. We also contacted *Home Power* magazine, and two of the editors responded immediately with some suggestions that we followed up on. But we still seemed to be at a dead end.

And then, in late October 2014, we received an unexpected, but totally welcome telephone call from the local insurance agent that our installer had recommended. Through determination and an understanding of our needs, they persevered and returned with an insurance quote from a reputable company to insure our shop building and the PV arrays—for less than we were formerly paying for insurance on the shop building alone.

As of October 26, 2014, the Barrington Motor Works shop building, storage building, and PV arrays are insured, and we are once again enjoying the renewable energy life in New Hampshire. We hope others can gain from this experience, and that the insurance industry gradually learns more about renewable energy technology so others can avoid our little speed bump.

Christopher & Barbara Betjemann • Barrington, New Hampshire

Courtesy Christopher & Barbara Betjemann

Solar Battle

We've been through quite the battle to use renewable energy at our on-grid home in the affluent city of Clarkson Valley, Missouri. Our house sits on 4.56 acres of heavily forested land, more than a football field away from the street, and is blocked by acres of oak and sycamore trees on all sides. I thought, "If the entire house is barely visible most of the year, nobody would care about seeing 1.5-inch-thick solar-electric modules on the roof." Boy, was I wrong.

Our first battle was with the city of Clarkson Valley. When we applied for a building permit, there were no laws on the books regulating solar energy systems. But upon receiving our plans and letter of approval from the local utility company and our homeowner's association, the city tried to block our project—the first of its kind in the city.

Instead of acting on our plans, the city took a couple of months to enact ordinances that played with the cost/benefit of solar energy systems (particularly on homes with complex roof lines), and imposed certain rules of aesthetics. We sought to comply with the reasonable requests of the city by moving half the modules from the roof of the house to a backyard ground-mount system.

At the same time, we submitted revised plans to our homeowners association (HOA). After 30 days, our attorney informed the HOA that their 30-day timeline had expired and we were proceeding with our system. The HOA was given several opportunities to litigate the matter, but they declined to do so.

The city's planning and zoning board recommended approving the system, but the city council members rejected it—without giving any explanation. We sued, won, and quickly installed our system. The city appealed, but we won again. The city was ordered to issue permits within one business day. Months passed and still no permits were issued. Instead, they demanded we reapply for permits under the new ordinance. We took the city back to court to hold them in contempt. The judge gave the city an ultimatum—either issue the permits and a certification of completion or be in contempt and pay us our legal fees. The city finally complied.

However, while we were waiting for the court to decide the contempt issue, our HOA voted on a special assessment—to fund a lawsuit against us over our PV system. The vote needed a two-thirds majority to pass, but only 25 of the 181 homes voted to fund the lawsuit. Even so, the trustees sued us!

Laws need to be changed in Missouri to protect the rights of property owners to use solar energy against "not in my backyarders" who don't want to look at it. No one should ever have to sue for the right to produce clean energy, much less be involved in two lawsuits over a system that can barely be seen from outside the property.

Frances Babb • Clarkson Valley, Missouri

Errata

On page 51 in "Assessing Green Building Materials" by Chris Magwood (*HP164*), the fuel consumption for freight trucks was reported as "0.3 gallons of diesel fuel per ton-mile," but should have read "0.03 gallons of diesel fuel per ton-mile."

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Wind is Hard

The leading statement in the "2014 Wind Turbine Buyer's Guide" (*HP161*) is right on—"Without question, wind is a tough renewable energy resource to tap."

I love the *Home Power* cover shots showing people strapped to a 100-foot tower while a crane, probably another 20 feet over their heads, tries to avoid dropping several hundred pounds of metal on them. Why anyone thinks this is glamorous is completely beyond me. Home-scale wind is dangerous, expensive, takes a lot of real estate, and is so much more involved than PV that—for all but the very few with unlimited time and resources—wind is a no-go. That should tell people capable of looking past the glamour to pass by wind energy.

Yes, I know the arguments about how wind complements PV, but at what cost? At a wind velocity of 11 meters per second, the small Kestrel puts out 1 kW, according to your comparison sheet. That's about three PV modules—which have a fraction of the cost, little or no maintenance, and 30-plus years of output with a 25-year warranty—not a five-year wind machine warranty.

And why are manufacturers publishing an 11 m/s wind speed's output—who has that kind of wind? It's unrealistic and a sad commentary on an industry that can't compete in the renewable energy business outside of large-scale commercial turbines. How is anyone realistically justifying wind?

Sorry, but this confirms my belief that wind has very little place in small-scale energy production.

Robert Dee • via homepower.com

Wind is a dynamic, and potentially destructive, energy source. Frequent maintenance is required to prevent system failure.

Courtesy Hugh Piggott

Small wind is not for the faint of heart. I talk most of my clients out of it, especially as the cost of PV modules continues to drop. For a wind-electric system to make sense, it requires a *great* wind resource; a dark and windy season (in the case of justifying an off-grid system); or a strong desire to just do it. It is a blast (if you like that sort of thing) to install and keep a system running, but it's not cheap, easy, or reliable.

One of the presenters at the recent Small Wind Conference gave a presentation titled "Go Big or Go Home," and I think there's a lot of logic to that. The economics and the equipment quality both improve as machine size increases.

"Wind complements PV" is a reasonable off-grid approach. On-grid, it's generally wiser to examine your resources and sink your money into generating energy with the most reliable and abundant resource—be that sun, wind, or falling water. With net metering, there's little need to have your generating source producing evenly all year. PV can make most of your energy in your sunny season (your utility credits the surplus to your account), and then you can draw on the credit during times of lower production.

I agree that the 11 m/s value is a bit high for a rating—but that is an instantaneous wind speed, *not* an average. And any instantaneous rating is pretty useless for comparison with PV or with other machines, and for energy predictions. What's really helpful is an *energy* rating at various average wind speeds, as shown in the article's table. Then you can (with luck) find the average wind speed at tower-top height at your site and get a prediction of the kilowatt-hours a given machine may provide each year.

A "1 kW" machine and 1 kW of PV are not comparable. A 1 kW PV system rarely produces at full power, but has a fairly predictable energy (kWh) output if you know the peak sun-hours at the location. A wind turbine rated at 1 kW peak is not similarly predictable, since wind is a cubic resource. For example, cutting the wind speed in half yields about one-eighth the potential power. You'll need to know the actual tower-top *average* wind speed to make a reasonable energy prediction.

You are wise to point out that the turbine cost is just one part of the system's cost. Typically, it's a small portion—in most cases, the tower and balance-of-system components each cost more than the turbine. Potential wind energy users need good pricing on the *installed* cost of all of the components before deciding to invest in a wind-electric system. Some will go for it regardless of the economics. In all cases, it's wise to know the costs and the benefits.

Ian Woofenden • *Home Power* senior editor

Battery Venting for Small Systems

I have a small 75 W solar-electric system that I use to charge three marine lead-acid batteries. I use it to power my ham radio station, minimal lighting, and a small inverter so we can watch TV during occasional power outages.

The battery's capacity is about 350 Ah, and the maximum PV short-circuit current is about 5 A. I have a charge controller that prevents battery overcharging. There seems to be no battery gassing from this setup, so I have not worried about ventilation and have the batteries in my house. However, I am thinking seriously about increasing our solar capacity—not to the point of replacing our normal electricity usage, but to have enough charging and storage to run the motors in our pellet stove during a winter power outage or keep our freezer running during a summer outage.

Should I be worried about keeping flooded lead-acid batteries inside the house? Should I either provide a vented enclosure or put the batteries outside? Is there a rule for an acceptable ratio of charging current to Ah capacity for using batteries as I am now using them?

Albert S. Woodhull • Leyden, Massachusetts

Keeping your batteries indoors in their own enclosed, ventilated space is usually the best practice, since this protects them from potentially damaging temperature extremes. Most renewable energy installers recommend a sealed, vented battery enclosure, no matter how small the battery bank or what battery technology is used.

Article 480.9 of the *National Electrical Code (NEC)* states that provisions for ventilation must be made to prevent the accumulation

of explosive gases, but the *NEC* doesn't go into the specifics. Under the *NEC*, sealed battery technologies don't require venting. American Boat and Yacht Council (ABYC) guideline 10.7.9 recommends a sealed, vented enclosure no matter what the battery type. Some local electrical codes even require power venting of the battery enclosure.

A properly designed and installed power system with a modern, three-stage charge controller keeps hydrogen gas emissions to a minimum (as with your present system), and battery technologies like sealed lead-acid don't gas during normal operation. But what happens when the situation becomes abnormal? A poorly programmed or malfunctioning charge controller can cause any battery to gas, and even "sealed" batteries have internal valves to release the gas and prevent a case from rupturing.

Battery banks also pose other hazards—exposed high-amperage terminals and wiring; corrosive buildup on the terminals; thermal runaway (with certain battery technologies); and the danger of spilling acid electrolyte. A mishandled wrench that shorts out a battery can turn red hot in a moment, not to mention giving a dramatic sound-and-light show for the unfortunate person who dropped it. Battery banks should be securely isolated from anyone who doesn't have any business with them.

So, that's the logic behind always using a vented battery bank enclosure. Most recommendations call for a minimum 2-inch-diameter PVC pipe vent from the top of the box, and a hinged, slanted lid, so any hydrogen gas rises to the top and out the pipe. Hydrogen is so light that it will find its way out even with a flat lid, but the slant also prevents the homeowner from piling things on the battery box lid. That makes access for regular battery maintenance easy, and gives quick emergency access.

Solar installer Jay Peltz works on a power vent for a new battery box.

Courtesy Ian Woofenden

For a typical flooded lead-acid renewable energy battery, the maximum recommended charge rate is usually about a C/5 (battery capacity in amp-hours divided by 5), tapering down during the final charging stages. But there are so many different battery technologies and manufacturers that you should be sure to follow the manufacturer's recommendations. Some modern charge controllers let you tell them the battery bank type, capacity, and recommended charge rates. Their circuitry then does the math for you, and sets up the controller automatically to keep your battery bank healthy.

Things aren't always normal, and lots can go wrong. Keep your batteries accessible but secure, and check on them regularly.

Dan Fink • Buckville Energy Consulting

write to:

asktheexperts@homepower.com

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Near Net-Zero

by Sarah Lozanova

Comment & Discuss this article @ homepower.com/165.26

Courtesy Steve Chiasson

In December 2013, an ice storm caused an extended power outage in Maine, leaving many residents scrambling to keep their pipes from freezing. But even with no utility electricity for five days, below-freezing temperatures, primarily overcast conditions, and no supplemental heat, the homes at Belfast Cohousing & Ecovillage (BC&E) lost only 2°F a day, on average, for a total drop of 8°F to 10°F. Nearby homes, by contrast, were below freezing after 24 hours.

How did they do it? Passive House design, passive solar orientation, and a small building footprint.

Courtesy Jeffrey Mabee

Courtesy Steve Chiasson

Small, Smart Design

The super-efficient ecovillage homes are heated largely by passive solar gain. Despite Maine's cold winters and relying on electric space and water heating, a 900-square-foot BC&E home can approach net-zero energy with a 3.5-kilowatt PV system, and a 1,500-square-foot home can zero out with a 4.5 kW system.

Although the homes aren't certified, the Passive House Institute US standards guided the design process. A southerly orientation; generous south-facing glazing; triple-pane windows and doors; lots of insulation; airtight construction; and a compact footprint resulted in a 90% reduction in the energy used for space heating compared to the average house. The homes share walls, reducing the exterior surface area and heat loss to the outside.

Above: Homes are clustered, leaving much of the property as open space; wide vehicle-free pathways for walking, biking, playing, and socializing connect the houses. Left: Traditional folk music and arts are embraced by many in the community and create lively social gatherings.

on a Community Scale

Twenty-two of the 36 high-efficiency homes in the Belfast Cohousing & Ecovillage already have PV systems that provide most of their energy needs.

Sarah Lozanova

Above: Through a community effort, paths are being beautified with fruit trees. Below: New members are eagerly greeted by volunteers to help unload the moving truck.

Courtesy Jeffrey Mabee

When designing the ecovillage homes, architect Matthew O'Malia of GO Logic used the Passive House Planning Package (PHPP), a spreadsheet-based design tool for architects and designers. "The Passive House standard is revolutionary in that it has spawned a new way of thinking around high-performance buildings," says Gibson. The PHPP energy model spreadsheet is used to determine a building's energy gains and losses. "You have a section of wall with certain properties, and the program can calculate how much heat is going to move through that wall over time. If you determine every way a building can gain or lose energy, you come up with a comprehensive model for how a building is going to perform."

However, Gibson points out, PHPP has its limitations. The software was designed in Europe and has been very accurate in predicting how the building will perform, but doesn't accurately model household electricity use in U.S. homes. "We use a lot more electricity than Germans do," he says. "And you can't predict occupant behavior, such as how someone might set their thermostat."

Even so, Gibson estimates that a 1,500-square-foot ecovillage home (without a PV system) uses $300 for heating each year (2,000 kWh at $0.15 per kWh), while a standard Maine home costs more than $2,500 to heat, using an estimated 680 gallons of fuel oil.

What makes the homes so energy-efficient is the attention to details, like insulation and air-sealing. The outer walls are a hybrid system: blown-in cellulose in 2-by-4 framed interior walls and 8.25-inch structural insulated panels (SIPs), achieving R-45. The load-bearing portions of the slab are 12 inches thick, with 4-inch-thick floors. The concrete slab is insulated with 6 inches of EPS rigid foam, slowing heat

Courtesy GO Logic

Builders from GO Logic erect the 8.25-inch structural insulated panels that form part of the exterior wall.

loss to the ground, and the ceilings have 24 inches of loose-fill cellulose for R-80. The house-wrap seams were taped to complete an air barrier, significantly reducing heat loss due to infiltration.

The triple-glazed wood-aluminum Unilux windows have an SHGC of 0.5 and a U-factor of 0.09. The R-7 windows and doors help keep the homes virtually airtight, and promote ventilation and summer comfort when open. The windows can swing inward on two hinges or be hinged on the bottom to tilt inward, opening at the top. The latter offers draft-free ventilation and prevents rain from entering the home.

Inside the SIP wall is a 2-by-4 framed wall filled with blown-in cellulose, bringing the total insulation value to R-45.

Sarah Lozanova

Heat-Recovery Ventilation

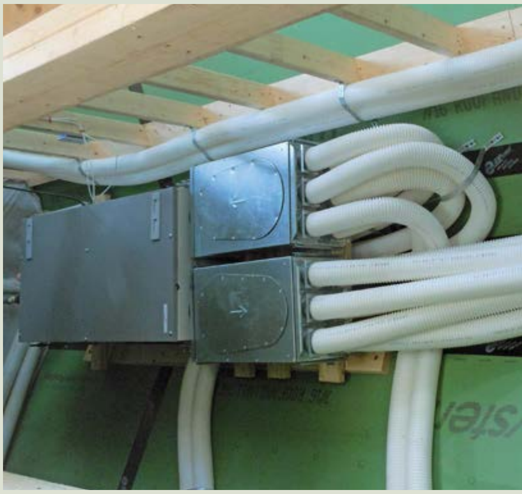
Airtight homes like the BC&E units need fresh air to ensure good air quality and avoid moisture issues. In cold climates, heat-recovery ventilator (HRV) systems are an energy-efficient solution for high-performance houses.

At BC&E, the Zehnder America HRV system continuously brings in outside air, filters and heats it with a heat exchanger, and supplies fresh air to the bedrooms. It draws stale air out of the kitchen and bathroom and transfers up to 90% of the heat to the incoming outside air before the stale air leaves the home. The ComfoAir 160 was installed in the one- and two-bedroom units; the ComfoAir 200 was installed in the three-bedroom homes. An integrated electric preheater was necessary on these units due to low winter temperatures and the potential for condensate freezing.

The HRV system helps maintain cool indoor air temperatures in the summer by working in reverse to cool the incoming air when outdoor temperatures are higher than indoor temperatures. When outdoor temperatures are lower than indoor temperatures (like at night), the intake air bypasses the heat exchanger to maintain pleasantly cool indoor temperatures.

The ecovillage homes contain no exhaust fans or vented hoods, to avoid exhausting hot air out of the home without recovering the heat. Manual switches in the kitchens and bathrooms allow residents to boost the system by increasing the air intake and exhaust speed on the HRV system after taking a shower, while cooking, or to remove odors more quickly than the HRV's default mode.

Sarah Lozanova



Each home has a heat recovery ventilator to supply fresh air while reducing thermal losses.

PV-Ready

Despite being clustered, the ecovillage houses shade each other very little, and only in the early morning and late afternoon. All of the homes are oriented either due south or within 30° of south, making them well-suited for PV and solar water heating systems.

Most of the homes have enough roof space for a grid-tied PV system large enough to offset the home's electricity using net billing. Some roofs also have room for a couple of solar collectors for water heating. The roof pitches vary—30° on the smaller units and 40° or 45° on the larger units. These angles are well-suited for year-round PV system performance and ease of winter snow removal. All of the homes are PV-system ready, with a junction box on the roof, concealed conduit running from the roof to the load center, and dedicated breakers in the electrical panel. To date, 22 of the 36 ecovillage homes have PV systems installed. One home also has a solar water heating system.

"It was nice to work on a project where there are a large number of folks who are interested in solar power," says John Luft of ReVision Energy, which installed the first 11 systems. Homebuyers were given the option of a PV system as part of the homes' feature selection process, and the option of including the system cost in the mortgage. GO Logic provided estimates of energy usage and a variety of solar options drafted by ReVision Energy that were customized to each home based on house size and number of occupants.

In the summer of 2014, residents organized a collective purchase for 11 additional PV systems, which were installed by Capital City Renewables (CCR). To receive wholesale rates on the PV modules and components, all of these systems used Axitec 250-watt PV modules with Enphase microinverters. The systems range in size from 2 to 5 kilowatts. Two BC&E members were trained and helped install the systems with the CCR crew.

With so many PV systems, Central Maine Power was concerned that the transformers couldn't handle the back-feed, and the utility required BC&E to commission a study. It was determined that numerous PV systems could be supported without upgrading the transformers, although CMP imposed a limit—no more than 150 kW of PV capacity. There was also concern about the "resiliency" of BC&E's all-electric homes when the utility grid goes down, considering that all the PV systems are grid-tied without battery backup. But so far, residents have—literally—weathered the winter storms with relative ease. Even without mechanical heating during a winter snowstorm and several-day utility outage, indoor temperatures remained relatively constant.

Sarah Lozanova (2)

All of the homes are duplexes and share a common wall, which reduces heat loss through the building envelope.

While the styles and details vary slightly from building to building, each was constructed on a strong premise of energy efficiency and livability. This made achieving net-zero-energy achievable, even with relatively small solar-electric systems.

Courtesy Peter McBride

All but one of the PV systems installed on BC&E homes use Enphase microinverters, which were mounted on the racking prior to installing the PV modules.

The ecovillage homes are all electric, in part because the 36 units are clustered on 6 acres of a 42-acre site. "There were a lot of discussions of whether or not to have wood heaters," says Alan Gibson, a principal for GO Logic. Because of air-quality issues and the heating loads of the buildings being so low, it made sense to install inexpensive electric-resistance baseboard heat.

Gibson estimates that using electric baseboards in every room, controlled by individual thermostats, instead of a conventional oil-fired forced-air central furnace, saved $15,000 in each 1,500-square-foot home, although other energy-saving techniques—such as the heat-recovery system ($3,000; see "Heat-Recovery Ventilation" sidebar); increased insulation ($17,000); and triple-pane windows and doors ($8,000)—added to the construction costs.

The mission of the ecovillage includes sustainability, so solar energy was part of the initial vision as a major source of energy for the community. "We didn't want to truck in deliveries of fossil fuels, so oil and propane were out," says Gibson. "If you can afford a PV system to meet all of your annual electricity needs, [electric heat in a super-efficient house] can be a greener alternative."

Maine's net-metering program allows customers to bank credit for surplus solar electricity for up to one year. Ecovillage homes have no air-conditioning and, in general, low electrical loads—so they usually earn credit from April to October. Once heating season rolls around, they can draw on the credit, as heating with electric baseboards drives up the electricity usage. Residents still pay a monthly fee to the utility for distribution; thus, the lowest electric bills are about $9.74. The energy credit appears on the electricity bill, further motivating homeowners to conserve energy to reach net-zero goals. All of the PV systems include access to MyEnlighten, an online monitor which includes historical and real-time energy production.

Typical Tech Specs

Overview

Project name: Grace/Mabee residence

System type: Batteryless, grid-tied solar-electric

Installer: ReVision Energy

Date commissioned: May 2013

Location: Belfast, Maine

Latitude: 44°N

Solar resource: 4.2 average daily peak sun-hours

ASHRAE lowest expected temperature: -17°F

Average high temperature (ASHRAE 2% design temp.): 86°F

Average monthly production: 484 AC kWh (estimated)

Utility electricity offset annually: 100%

Modules: 18 Canadian Solar CS6P-255M, 255 W STC, 30.2 V Vmpp, 8.43 A Impp, 37.4 V Voc, 9.0 A Isc

Array installation: IronRidge XR roof mounts on 40° tilt south-facing roof; parallel-mounted

Microinverters: 18 Enphase Energy M215-60-2LL-S22/S23, 215 W rated output, 270 W VDC maximum input, 27–39 VDC MPPT operating range, 240 VAC output

System performance metering: Enphase My Enlighten

System Costs

Initial Cost: $15,275

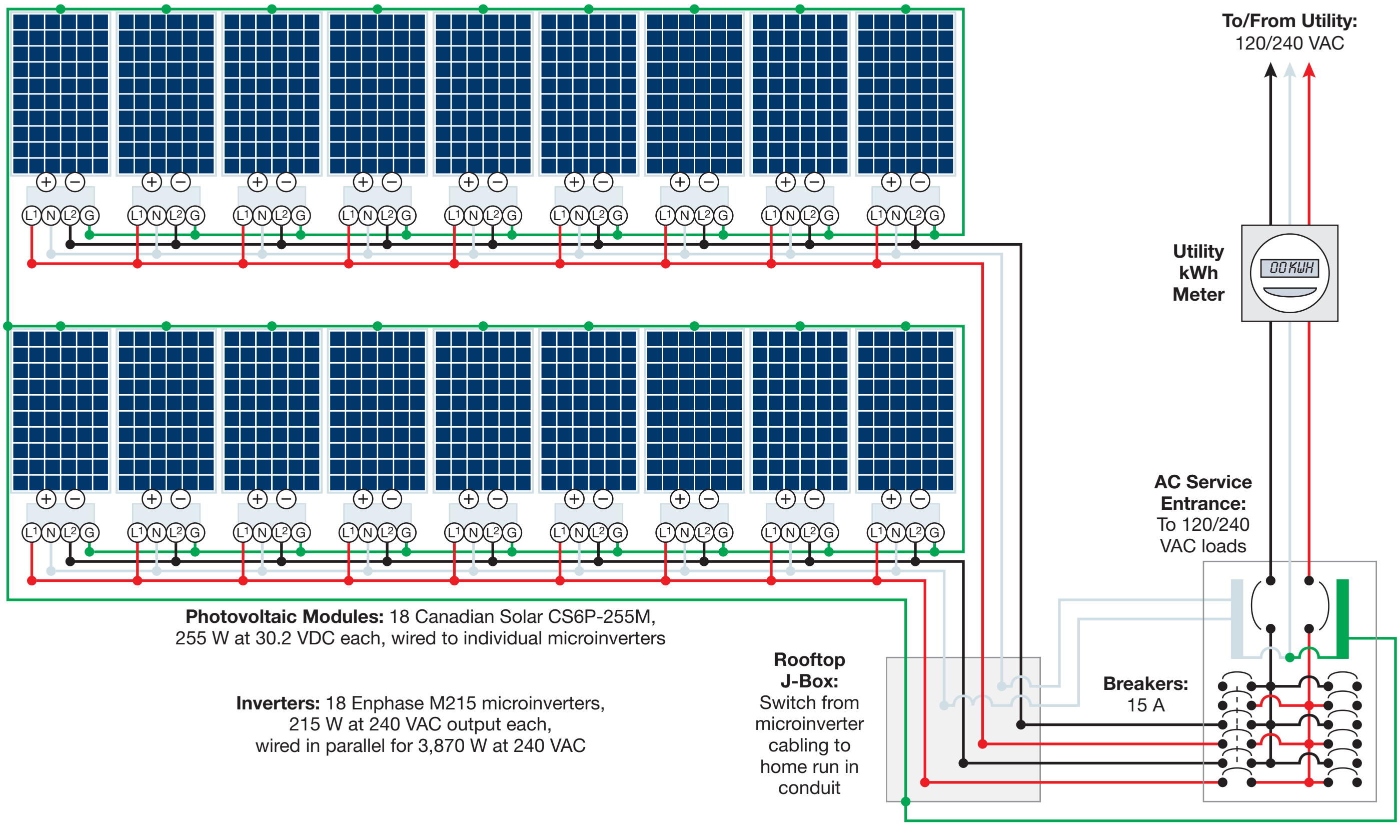
Incentives, rebates & tax credits: $2,000 (Efficiency Maine)

Federal tax credit: $3,983

BC&E community members and a Capital City Renewable crew member (also a BC&E member) install a 5-kilowatt PV system of Axitec 250-watt PV modules on the author's home.

Sarah Lozanova (2)

Example BC&E Batteryless Grid-Tied PV System



Note: All numbers are rated, manufacturers' specifications, or nominal unless otherwise specified.

The first 11 systems at BC&E were installed by ReVision Energy, using Canadian Solar modules (see the schematic above, which reflects a typical system).

Courtesy ReVision Energy

Kiril Lozanov organized the bulk PV module purchase to help keep costs down.

Courtesy Jeffrey Mabee

Custom Conservation & Efficiency Measures

BC&E homeowner Penny West has numerous ways that she reduces her energy use to achieve her net-zero goal with her 4.3 kW PV system, such as using only a 6-cubic-foot refrigerator with no freezer. "I also take advantage of the fact that the breaker panel is in the entryway. I turn on the water heater in the morning before I take a shower and turn it off when I'm done."

One ecovillage member placed a bulk order for 400 LED lights, reselling the discounted 3.5 W bulbs to residents who were interested in replacing the 50 W halogen bulbs that came with the original track lighting systems. Some members installed low-flow showerheads that use 1.25 gallons per minute (reducing water use and water-heating loads), forgo a clothes dryer, or put timers on their water heaters to reduce standby loss. When the common house is complete, shared group dinners will reduce individual cooking energy consumption.

Although nobody has moved forward yet, there is interest in installing PV systems on the garage roofs to offset electric-vehicle charging. The garages have moderate solar potential, with orientation up to 30° off of south and some shading from houses. With downtown Belfast just 2.5 miles away, electric vehicles are a viable transportation option for ecovillagers.

PV System Design Loads*

Item	kWh / Year	kWh / Month
Space heating	1,300	108
Appliances & lights	2,000	167
Water heating (per person)	1,350	113
Total Energy Use	4,650	388

*For a 900-square-foot BC&E home

web extras

"Passivhaus in Chapel Hill" by Stephen Hren in *HP152* • **homepower.com/152.88**

"Heading for Zero: Smart Strategies for Home Design" by Jim Riggins in *HP141* • **homepower.com/141.88**

"The Passive House—Strategies for Extreme Efficiency" by Katrin Klingenberg & Mike Kernagis in *HP138* • **homepower.com/138.70**

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Efficient Home Lighting Choices

by Chris Calwell

In the past, CFLs were promoted as the energy-efficient lightbulbs of choice for virtually all applications. But what may be a great light for reading and entertaining in your living room, for example, may not make the best light for food preparation tasks in your kitchen.

Instead of trying to put a CFL in every socket, savvy homeowners interested in energy efficiency are increasingly pursuing a more nuanced strategy: Choose the right technology for each application to deliver optimal performance and cost-effective energy savings.

Understanding Lighting Terminology

The most familiar (but perhaps the least useful) way of comparing lightbulbs to each other is wattage, which tells you how much power is consumed but tells you nothing about how much light the bulbs will provide—or whether you will like their light quality. Other key terms include:

Wattage Equivalent. Most energy-saving lightbulbs claim wattage equivalent, often in bold, colorful text at the top of the package. Ignore this! The federal government declined to regulate how manufacturers calculate and report wattage equivalency, so the claims products make are all over the map and often deceptive. It's smarter to shop on the basis of measured light output instead (see the "Lumens Equivalent" table for comparative information).

Lumens are the measure of the absolute amount of light a bulb provides. An integrating sphere is one measuring tool that's used. It first captures the bulb's total light output in all directions across all the different wavelengths of light. Then it weights the resulting values to reflect the human eye's sensitivity to each wavelength, summing up all the weighted values to give an overall measure of "useful" light output. Dim bulbs may only deliver 200 lumens or so, while really bright ones can deliver 2,500 lumens or more.

Efficiency. If one lighting technology can deliver more lumens of light per watt of power consumed, it is said to be more energy efficient. Lumens per watt is the figure of merit for efficiency, but that almost never appears on product labeling or packaging, so you have to calculate it from the values that are provided separately. For example, say a standard 60 W

Ben Root

incandescent is rated at 750 lumens—that's 12.5 lumens per watt. Compare this to a 14 W compact fluorescent rated at 900 lumens—that's 64.3 lumens per watt. Efficiencies can range from as little as 5 to more than 100 lumens per watt, depending on the technology you choose and the amount of light you need.

Lifetime is now reported in years on product labels and assumes three hours of operation per day (a little higher than typical usage according to utility studies). Also, remember that the difference between a projected lifetime of 20 years and 25 years on two products is probably not meaningful, given the uncertainties in the accelerated lifetime testing process and the degree to which new lighting products will continue to improve between now and then. From a practical standpoint, the warranty a manufacturer offers is more useful; the highest-quality products usually offer a 10-year warranty.

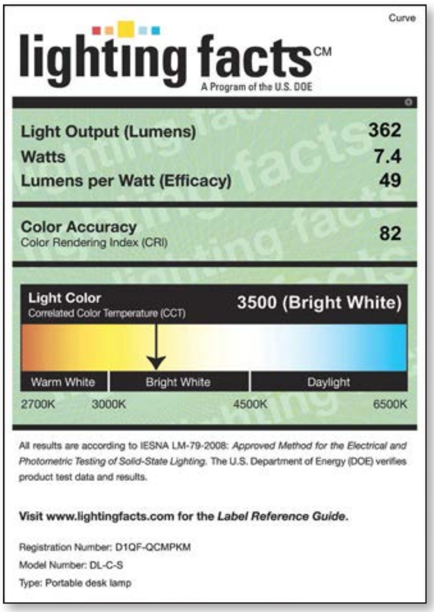
Color rendering index (CRI) tells you how accurately a bulb renders a particular subset of colors (primarily pastels). A CRI of 80 or greater is usually recommended by lighting experts, but there is debate in the lighting community about the merits of paying extra money for products with a CRI greater than 90—most users can't tell the difference under typical household lighting conditions.

Correlated color temperature (CCT; reported in Kelvin, K) tells you how "warm" or "cool" the light from a bulb appears. Residential users typically favor warm (approximately 2,700 K) CCTs similar to incandescent bulbs, or 3,000 K (similar to halogen bulbs). In the 4,000 K to 6,000 K range, the resulting light can appear bluish. It is common for people who live in very sunny and tropical locations to favor bulbs with higher CCTs, given their greater similarity to daylight or midday sunshine.

The Energy Star label appears on energy-efficient products that deliver good performance in most of the attributes listed above. But thousands of models now qualify for it, so you need to be more selective to find the best performers. Also, be aware that many new energy-saving lighting products are introduced to market a few months before they have completed enough accelerated lifetime testing to earn the Energy Star label. The manufacturer will later change the packaging to reflect receipt of that certification, but the product inside the package can often be the same as the one selling a few months earlier without the logo. This means that the most recently introduced models without an Energy Star logo can occasionally be more efficient and affordable than older models that are labeled.

More specialized information can often be found on product packages or manufacturer websites, including beam angle and center-beam candlepower for reflector lamps, compatibility with common dimmers, etc. If you are buying a large number of efficient bulbs, check online reviews to find products that have been consistently popular with other users, or buy from a retailer that will allow you to return the products for a refund if you are unhappy with their performance.

Some products will bear the U.S. DOE's Lighting Facts label, which helps identify a bulb's characteristics, such as light output, efficacy, and color rendering.



Courtesy lightingfacts.com

Lighting Technologies

Incandescent bulbs employ a thin tungsten filament that conducts enough electricity to glow white hot. Although this technology is more than 100 years old now, it has received only a few upgrades since Thomas Edison's original invention. However, incandescents remain widely available on the market, but most are now filled with halogen gas to allow them to comply with federal energy-efficiency standards. Unfortunately, the federal standards were drafted in such a way that many manufacturers are meeting the new power limits by making their lamps dimmer. So it takes careful label reading and comparison-shopping to get a true replacement. Use the "Incandescent Replacements" table to ensure that the halogens you buy are just as bright as the old incandescents you are replacing.

For example, if the new halogen bulb you are considering claims to replace a 75 W incandescent but only provides 900 lumens, it's really more like a 60 W incandescent—and won't give you enough light. General Electric sells a Reveal halogen bulb that claims to replace a standard 100 W incandescent using only 72 W, but it only provides 1,120 lumens. It is barely bright enough to replace a standard 75 W bulb, yielding almost no energy savings!

Lumen Equivalents for Incandescent Replacements

Incandescent Watts	Lumens
25	250–449
40	450–799
60	800–1,099
75	1,100–1,599
100	1,600–1,999
125	2,000–2,549
150	2,550–3,000
200	3,001–3,999
300	4,000–6,000

Many types of halogen bulbs cut power use by 25% to 30% but often cut light output substantially as well, barely improving efficiency. Modified-spectrum halogens (the bulbs' glass has a bluish-purple hue) are the worst offenders—avoid them. When buying halogens, look for infrared-reflective (IR) models with special low-e coatings that bounce heat back onto the filament while letting visible light pass through. This allows the best incandescents to deliver more lumens per watt.

The old-fashioned incandescent lamps that remain legal to sell without halogen gas largely fall into particular niche product categories like three-way, vibration-resistant, and extremely bright (more than 2,600 lumens). Avoid these products as well—there are more efficient choices.

A new, promising incandescent technology potentially doubles the efficiency and life of standard incandescents by using IR coatings to reflect bulb heat back to the filament, which makes it even brighter. These bulbs may achieve a remarkable 32 to 37 lumens per watt, compared to the 7 to 18 lumens per watt seen with typical incandescent bulbs. CFLs and LEDs are still more efficient than these new incandescents, but can cost more and have subtle differences in color quality.

Incandescent lighting is mostly being replaced by more efficient technologies. The exception may be 2X bulbs, which use selective-surface coatings to reflect heat back toward the filament. They have all the benefits of a standard incandescent, but twice the efficiency.

Courtesy Vybrant (2)

Incandescents

Halogen incandescent technology can be more efficient than traditional incandescents, but the technology is often used to boost the bulb's lifespan.

Compact Fluorescents

CFLs, long considered the best choice for energy efficiency, have drawbacks like lack of dimmability, temperature sensitivity, and light quality. But products are improving all the time.

Courtesy Firefly; Feit; Chris Calwell

Compact fluorescent lightbulbs (CFLs) are widely available in a range of sizes, prices, and light levels. They have miniaturized the technology found in typical linear fluorescent lamps, bending the tube into a small amount of space. Thousands of models are now Energy Star qualified, and many utilities provide rebates for them.

Although they were once the only affordable energy-efficient lighting option, they come with caveats. CFLs do a reasonable job of rendering many colors, but they don't render all colors well—and that's easily noticed by people with particularly sensitive vision. Others have concerns about how to avoid mercury exposure if they get broken, and how to safely dispose of them. (Note that most analyses have found this to be secondary to their other environmental benefits, since their energy savings results in mitigating much greater mercury emissions from fossil-fuel power plants. See *HP153*, "CFLs & Mercury.")

CFLs are also not usually dimmable, and can overheat in enclosed fixtures. This helps to explain why they are broadly used in some homes but rarely in all of a home's light fixtures.

CFLs typically operate at about 50 to 70 lumens per watt and will run for about 8,000 to 18,000 hours before burning out. While they offer a low-cost way to save on lighting energy, they are increasingly being displaced by their better-performing cousins—LEDs.

Courtesy iledhn.com

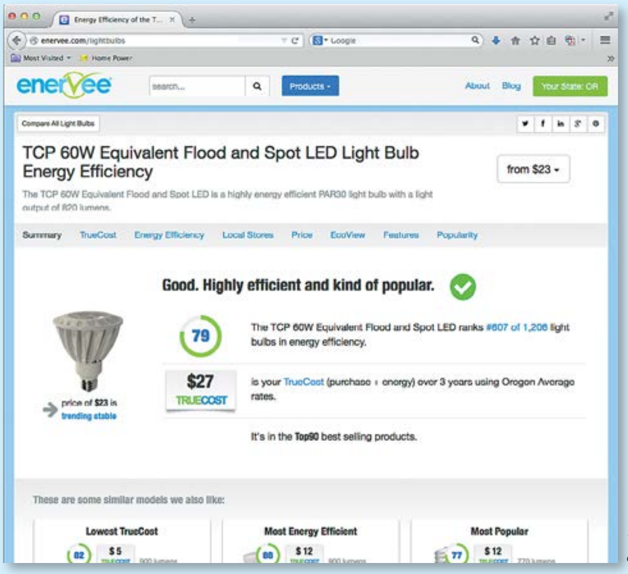
Chris Calwell

LEDs

LEDs offer the best lumens per watt efficiency, with constantly improving features like color temperature and beam width.

LED Reflector Lamp Ratings

Check out which LED lamps deliver the highest efficiency, best performance, or best cost-effectiveness at Enervee.com or toptenusa.org. Both sites can help you narrow down your options from the thousands of Energy Star models available.



Courtesy enervee.com

Light-emitting diodes (LEDs) are quickly gaining ground as the most energy-efficient lighting technology. Although early LED models were bulky, expensive, and not very bright, those products have yielded to a new generation of quality products that use 10% to 30% less energy than CFLs, are easier to dim, and last far longer.

LEDs once operated in a similar efficiency range to CFLs, but can now achieve 85 lumens per watt across a wide range of light output levels, and best-in-class LED designs are headed to 100 lumens per watt—and beyond.

You can find comparisons of more than 17,000 LED lighting products, including information on lumens, watts, efficacy, color rendering index, and correlated color temperature, at lightingfacts.com.

The difference in color quality among incandescents, CFLs, and LEDs can be seen in the spectral distributions graph, which show how much of the light from each source falls within each wavelength of the visible spectrum, and compares that to the human eye's sensitivity to each of those wavelengths (dotted curve). Note that incandescents (halogens) and LEDs both offer a continuous spectrum of colors, but incandescents tend to be dominant in the reds and fairly limited at the blue end of the spectrum. LEDs are often the reverse. CFLs, on the other hand, only emit light within certain portions of the visible spectrum, so can disappoint some users who are particularly sensitive to subtle color differences.

LED lighting for many applications is now available at your local hardware store.

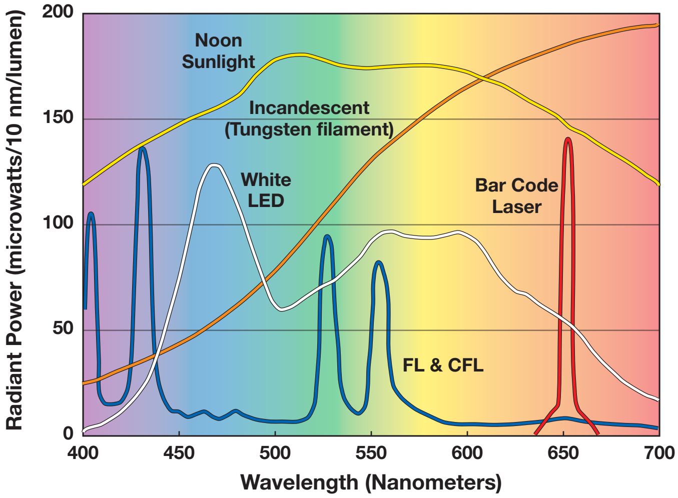
Ben Root

Matching Bulb to Application

Most home applications call for omnidirectional sources of light. "General service" bulbs work well in many kinds of table and floor lamps, enclosed globes, pendant fixtures, and other types of narrow light fixtures that mount close to the ceiling or wall. LEDs are a great option, but make sure they are truly omnidirectional. Many older models that have a snow-cone appearance shine most of their light upward.

Most down-lights are designed to accommodate particular reflector lamp shapes and sizes. PAR (parabolic aluminized reflector) lamps work best in deep ceiling cans and R (reflector) lamps work better in shallow ones. The diameter of the opening tells you what size of bulb to purchase. If the opening is a little less than 5 inches in diameter, a PAR 38 works well (the 38 refers to 38-eighths of an inch in diameter, or 4.75 inches). PAR 30 or PAR 20 bulbs tend to work better in smaller openings. Bulged reflector (BR) bulbs will also fit in the same ceiling cans, but tend to have very poor efficiencies, in part because their reflectors do not do as good of a job at gathering and aiming the light. The reflector lamp technology you choose is also application-specific. In general, CFL reflectors are not a good choice—their light is too diffuse. The most efficient halogen technologies can be a reasonably good choice, particularly IR halogens. LEDs are the most efficient

Spectral Distribution of Lighting Technologies



Different lighting technologies create light in different spectrums affecting light color and mood, and thus appropriate application.

choice, though still a bit expensive. Their directionality and dimming capability give them some natural advantages in this application, and their long lifetimes (20,000 hours or more) can be a plus, given the relative inconvenience of reaching and replacing many down-lights.

A wide variety of specialized lighting applications are not commonly served by the three major lighting technology types. If you want to distribute light uniformly over a very broad area, for example, it's hard to beat linear fluorescent lamps for affordability and for even light distribution. Some manufacturers have begun producing linear LED "tubes" that can be inserted in place of these fluorescent lamps, but most still struggle to compete with the uniformity of linear fluorescent lighting at a reasonable cost. Linear fluorescent tubes that were 1.5 inches in diameter (T12s) have now given way to 1-inch-diameter lamps (T8s) and even 5/8-inch-diameter lamps (T5s), for improved efficiency and performance (see "Changing Fluorescents to LEDs" in this issue).

Efficient Lighting for Efficient Homes

Using the most efficient lightbulbs is especially important in zero net-energy (ZNE) homes or off-grid homes powered by renewable energy systems. The extra energy saved by using LEDs compared to CFLs, for example, is also cost-effective when compared to more PV modules and equipment for meeting the larger overall loads (see "Save on PV" sidebar).

LEDs also offer a wider range of color choices than CFLs, making them a more seamless integration with passive solar homes that rely largely on daylighting. For instance, using LEDs with a CCT between 3,000 K and 3,500 K in rooms with good natural light will help keep the light color more similar as the lights come on in the evening. Likewise, some LEDs shift their color temperature as they are dimmed, making them a good match with solar homes that get flooded with "warm" temperature sunlight at sunrise and sunset.

Purposeful Lighting

My recently completed ZNE house in Durango, Colorado, uses LEDs in almost every fixture, inside and outside. Linear T5/fluorescent lighting is used in the laundry room and master closet, and pin-based CFLs are used in one ceiling fan. Incandescent lamps are used in only a handful of aesthetically critical applications like the red glass and seashell mosaic pendant lamps over the kitchen island, the fully dimmable dining room fixture, and the small, wall-mounted reading lamps next to our bed, where the extra warmth of the light's appearance is worth the energy-efficiency trade-off. Our brains interpret red light—similar to the light from a flame or a sunset—as a cue to go to sleep. By contrast, our brains interpret blue light from CFLs or most LEDs—similar to the light from a TV, computer monitor, or cell phone—as a cue to wake up.

While the lighting in most homes can consume 1,200 to 1,800 kWh per year or about 15% of total electricity use, our estimated lighting energy use is only about 400 kWh per year. The light source we used most widely in the house was the Cree screw-based 800-lumen LED, purchased for $10 to $13 apiece. We also relied heavily on a new type of Sylvania LED down-light that surface-mounts directly to electrical junction boxes in new construction, eliminating the need for a down-light fixture or its penetration through the insulation. These fully dimmable products were about $35 apiece, and distribute the light very evenly and unobtrusively into the room. High-quality Soraa LED MR-16 bulbs are used in low-voltage track light fixtures.

Save on PV

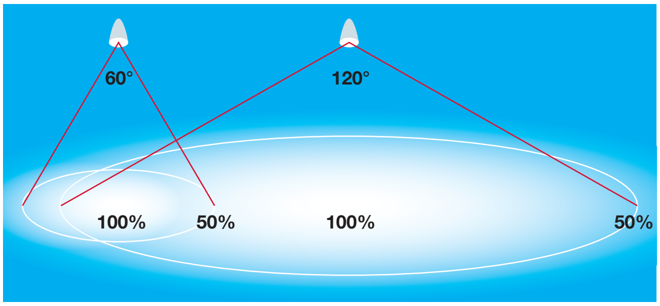
Using efficient lighting can decrease the size of the PV system you'd need to offset your household loads. The price of both PV modules and LEDs has declined in recent years, while performance has improved due to economies of scale and technological advancement in semiconductor manufacturing. But if you wanted to offset, say, 1,000 kWh a year, which is the better deal?

There are a lot of variables involved, but if we assume 2,000 peak sun-hours per year and a PV system cost of $4 per installed AC watt, the cost of delivering an additional 1,000 kWh would be about $2,800.

On the lighting side, 60-watt incandescents that previously cost $0.30 apiece can now be replaced by LEDs drawing 10 W and selling for $10 apiece. Each LED is projected to last as long as 25 incandescents, so its incremental cost for a comparable 25,000-hour service lifetime is $2.50. If we assume 3 hours of bulb use per day, each would save 55 kWh per year. Replacing 18 incandescents in your home with LEDs would save you 1,000 kWh per year, for an upfront incremental cost of about $45. The total out-of-pocket capital cost would only be $180 (giving no credit for savings on future incandescent bulb purchases).

Either way, it's at least 94% cheaper to save the 1,000 kWh per year with LEDs than it is to generate it with additional PV system capacity. This supports the expert advice of "efficiency first" in solar homes.

Beam Angle



Matching beam angle to the lighting task is important—wide for area and ambient lighting, or narrow for task lighting. Until recently, LEDs were hampered by narrow beam angles, but that is changing.

web extras

Check out these related articles at HomePower.com:

"LED vs. CF vs. Incandescent" by Kelly Davidson • **homepower.com/158.10**

"Ask the Experts: Efficient Lighting" by Dan Fink • **homepower.com/156.30b**

"Mercury & Fluorescent Lights" by Andy Kerr • **homepower.com/153.12**

Besides its energy savings, our energy-efficient lighting looks warm and welcoming. On a public tour of the house last spring, the most common remark we heard from visitors was how pleasant and attractive the lighting was. We should never forget that a lightbulb's primary purpose is to provide excellent light. No matter how much energy they save, they will never gain widespread acceptance unless they light up a room attractively as well.

Fueling with Sunshine

by Brad Berman

For many electric vehicle (EV) drivers, it's only a matter of time before this idea pops up: Why don't I install PV modules so I can run my car on sunshine?

Courtesy Tom Moloughney

Our research suggests that approximately one in three EV owners has a home grid-tied PV system. The one-two punch of EV and PV can break the ties between driving and burning fossil fuels—including the coal, natural gas, or other nonrenewable energy sources used by utilities to produce electricity.

PV & EV Work Together

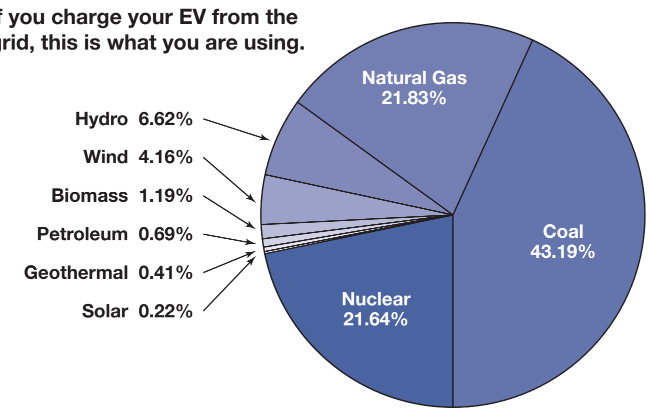
At first, you might think of putting PV modules on top of your car—but due to the efficiency of PV modules and the limited size of a car's roof, the amount of energy that can be produced isn't going to help much. Even if you covered the 16 or so square feet of your EV's roof with PV, on a day of full sun, the energy would cover only a couple miles of driving. The small PV spoiler on the Nissan Leaf is good only for recharging the car's 12-volt accessory battery. And you've probably seen lightweight, low-speed solar concept cars with huge roofs to increase PV surface area.

But a more realistic approach is to use a large-enough grid-tied PV system to offset the daily energy you're using to charge your EV. When your home PV system is producing power during the day, any appliance that's running in the house—lighting, television, or an EV charging station—is directly fed by solar power.

Even when you charge at night—as you should, because it's often cheaper and greener (see "Utility Power Can Be Greener at Night" sidebar)—your electric car can benefit from clean home-produced electricity. Here's the reason: the PV system is tied into the grid—pumping excess electrons out to be shared by all utility users. Think of the grid as an energy bank, where you deposit green power when the sun is shining, and withdraw those energy credits when you need them.

U.S. Grid Electricity Mix

If you charge your EV from the grid, this is what you are using.



Data courtesy Lawrence Livermore National Laboratories

Environment & Economics

In many regions of the country, electric utilities rely heavily on fossil fuel as a source. This inspires one viewpoint that EVs are not much greener than a Prius-like hybrid or a small fuel-efficient internal combustion engine-powered car like a Ford Fiesta. Having a grid-tied PV system can put a quick end to this concern.

But even if the environmental question is somewhat settled, debates on the economics of EV and PV are less easily resolved. The traditional argument against both PV systems and electric cars is that you are paying more upfront—on expenses that might take years or decades to pay back through reduced energy and gasoline expenditures.

Arguments for or against these investments are elusive. As usual, the devil is in the details—with a broad set of variables, including:

- the utility rate in your region (huge factor)
- how much you drive
- amenities of the vehicle
- amount of energy you use at home
- amount of sunlight that hits your roof
- PV system cost
- available incentives (for both the EV and the PV system)

Utility Power Can Be Greener at Night

Typically, the "brownest" utility energy is produced during peak power consumption—usually during the daytime—when "peaker" power plants have to be brought online to supply the additional demand for electricity. These power plants are typically powered by diesel or other petroleum fuel.

At night, when the grid is not being drawn on as heavily, utility power tends to be greener. This can be especially true if utilities are tapping into wind power, which could be used to charge EVs.

Onboard PV is only adequate for specialty vehicles like this Solar Challenge endurance racer—there's no room for groceries.

Courtesy Tokai University

Courtesy Tom Moloughney

Only stopping for directions…

Now add all the uncertainties regarding financing plans for both your car and PV installation—and add in unpredictable and unstable oil and electricity prices. Finally, don't forget to include the resale value of an electric car. Even if upfront costs are not recovered during the period of ownership—by cheaper fueling and maintenance—any difference is commonly recouped upon sale of the car. Similarly, the value of your home is often increased after adding a PV system. It's a home amenity (like granite countertops), but one that saves money each month.

For EV drivers, the cost calculation for a PV system is enhanced both by displacing the expense of utility-supplied electricity and the expense of roller-coaster gasoline prices. After you've paid off your PV system, the energy generated for your car (and/or home) becomes free.

System Sizing for an EV

For offsetting your EV charging with solar, a system capacity of 2.5 kW is generally a good fit. That's the size specified by Ford and SunPower for a special bundled deal for a PV system to power a Ford Focus Electric car.

That size assumes that the average output of a 2.5 kW system is about 3,000 kWh per year. If you use a somewhat-generous estimate of 4 miles of driving for every kWh of electricity put in your car, it means about 12,000 miles of driving powered by the sun, each year. This provides a general estimate, so PV systems in sunnier climates can be smaller; cloudier climates will need a larger one. For example, to produce 3,000 kWh per year of solar electricity in Albuquerque, New Mexico, a 1.8 kW system might be all that is required. In Seattle, Washington, you'd need a 3 kW system to produce that same amount of energy.

web extras

"Green Car Drive-Off: EV vs. Hybrid vs. Gas" by Brad Berman in *HP141* • **homepower.com/141.16**

"EVs Don't Cost Much To Run" by Brad Berman in *HP153* • **homepower.com/153.46**

Courtesy Tom Moloughney

The EV charging station needn't be near the PV array, nor does charging need to happen when the sun is shining.

It's really liberating being in control of your own energy like this. Also, by being more efficient in my household, I have reduced my electric use for my house nearly as much as my car needs to charge—so I'm pretty much driving for free, just by being more efficient. You can never say that about gasoline.

—Tom Moloughney, PV & EV owner

Of course, you may also want the system to generate green power for your home. You can look at past electricity bills to determine how much energy you are using each month. Depending on your budget, you might decide to have a PV system offset only a portion of your charging or home energy usage. Regardless, knowing how much energy your home and car require is the first step.

Solar & EV Leasing vs. Owning

In part, the recent rise in grid-tied residential PV systems can be credited to the availability of leasing plans, which allow little or no money down on a PV system. A third-party solar-leasing company can reduce your upfront cost, while keeping your electricity costs about the same as before the installation.

The rates you pay for electricity are locked in for a decade or more—a period of time in which the system is monitored (and guaranteed) to produce a certain amount of energy. These plans are profitable for the leasing company, because it immediately pockets rebates and tax credits—while providing income and over time depreciating the value of the system (which they own and you rent).

It's somewhat similar to leasing an electric car, which has a lower monthly payment because the dealer applied the incentive to the cost basis. In general, PV system leasing (which involves finance charges) makes more sense for people with high energy bills and heavy EV use.

However, EV owners can cash in on incentives by buying the PV system outright or financing it themselves through personal loans, construction loans, or mortgages.

Installers & Bids

Unless you are the hardcore DIY type, you'll need a solar installer to manage your home power project. We recommend reputable, experienced PV installers—rather than box-store solutions—to guide you through every step of the process, including:

- deciding if solar is right for your site
- choosing the best hardware
- finding the best placement on your roof or property
- managing financing and incentives

Start by compiling a list of prospective installers—word-of-mouth referrals from family and neighbors are helpful, although online reviews can be a starting place, too. The North American Board of Certified Energy Practitioners (NABCEP) offers professional PV installation certification and provides a standard to look to when you're considering an installer.

System cost is often the bottom line, but most installation estimates should be competitive, so other factors should come to the forefront—such as trust that your installation will operate well for the next 25 years and that the installer will be available to answer all your questions. A good installer will act like a partner throughout the process. Use any proposals to do your own research, and compare the differences between bids in dollars, experience, and technology.

EV Incentives

New EVs with a battery pack of 16 kWh or more qualify the buyer for a federal tax credit of $7,500. EVs with smaller batteries also qualify for a federal tax credit, but on a sliding scale based on battery size. There often are additional incentives available at the state and, sometimes, utility levels. Seek guidance from your installer about incentives, financing, and system leasing versus owning (see "Solar & EV Leasing vs. Owning" sidebar).

web extras

For a list of EV incentives state by state, check out **bit.ly/EVIncentives.**

Choosing a "Charger" (EVSE)

An electric car's charger is on board the vehicle—buried in the car's guts to convert AC from your house to DC for charging the car's propulsion battery. People still call the wall-mounted box that supplies 240 VAC to the car a "charger." But that box, cord, and plug is actually called electric vehicle service equipment (EVSE)—and if you have an EV, you'll want to install one at home, since it allows faster charging compared to charging with a standard 120 VAC plug. An EVSE allows EVs to safely connect to a 240 VAC source. It's not rocket science, but there are important differences between the various EVSEs, and there are a few best practices to keep in mind.

Cost. A capable and durable EVSE will usually cost between $600 and $700, plus installation. You could spend a little bit less or twice as much, but that's the ballpark. Portability and connectivity can send the price higher.

Amperage capacity. Your EVSE should handle at least 30 amps. The (somewhat optimistic) estimate is that an hour of 30 A charging will yield about 30 miles of range. Fifteen amps will yield about 15 miles in an hour of charging. (Note: A 30 A EVSE requires a circuit breaker rated for at least 40 A.)

Most plug-in *hybrids* (and the Nissan LEAF prior to the 2013 model) don't take full advantage of that fast a charging rate. But it's still wise to have the capacity to charge at least at the 30 A level because you won't have to upgrade in a few years if/when you buy a new EV that has a more powerful onboard charger. Also, it's nice to allow friends with faster-charging EVs to get a full charge from your garage.

Length of charging cable & EVSE location. Imagine where your electric car will be parked and where the ideal EVSE location will be. Now measure the distance between the EVSE location and where the car charging port will be. Cables are usually 15 to 25 feet long. Make sure your cord can easily reach where it needs to go, and consider if it could also reach a potential second plug-in car in your driveway or garage.

An EVSE charges an EV more quickly than using a standard 120 VAC outlet.

Courtesy plugincars.com

Courtesy AeroVironment

Depending on your skills, it may be best to have an electrician install your EVSE.

An electrician might have to run conduit, the length depending upon placement. Longer runs add installation cost, but convenience is important because you'll charge almost every night.

Portability. If possible, don't hard-wire your EVSE. Have an electrician install a NEMA 14-50 outlet or similar (the types of outlets used for things like clothes dryers). Then put a matching plug and cord on your EVSE so you can mount it next to the outlet, and simply plug it in. If the time comes when you move or decide to relocate your EVSE, simply unplug it—and plug it back into another NEMA 14-50 outlet. This approach costs about the same as a hard-wiring, but makes the EVSE moveable with less additional expense. If your EVSE is outside—maybe you don't have a garage—then local code might require that you hard-wire the charging equipment. Otherwise, keep your options open.

Connectivity. In this age of smartphones, smart grids, smart this and smart that, you might feel compelled to buy a Wi-Fi-enabled EVSE. That might not be so smart after all. While these fancier products sound cool because they have timers, meters, touch screens, and capabilities for monitoring and changing charging events over the Web, that connectivity adds unnecessary complexity and cost. In some cases, when connectivity is lost, the EVSE can shut down—leaving your EV uncharged. Many of these remote controllable features are already available directly on the car, or from mobile apps. So, the smart money is on "dumb" but durable EVSEs.

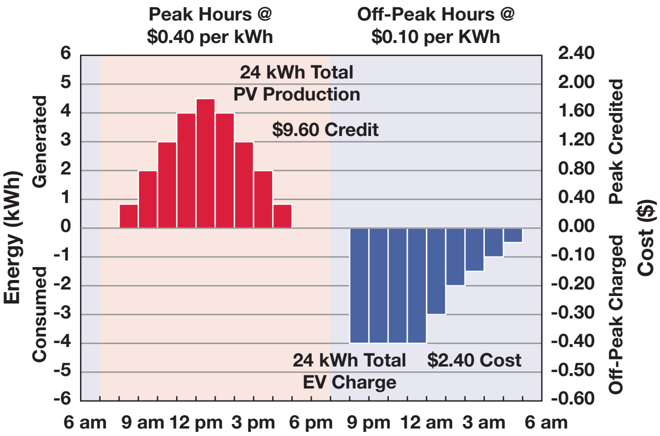
If tracking your EV's electricity use (for work or tax purposes) is a must, you can either meter your charging separately, or wait for add-on devices that integrate with the smart grid. These solutions are currently being evaluated in pilot projects.

Check out "Gear" on page 14 in this issue for a rundown of available EVSEs.

Timing It Right

Time-of-use (TOU) electricity rates are an effective tool utilities use to discourage EV charging (and other electricity use) during peak electricity demand hours. TOU rates therefore reward households with net-metered PV systems that produce an excess of energy during the day, and use energy off-peak.

PV Production with Net & TOU Metering



In this TOU scenario, a 5 kW PV array could realize a net profit of $7.20 on a sunny day.

That daytime surplus is credited at a higher rate; utility energy drawn at night is purchased at a lower rate.

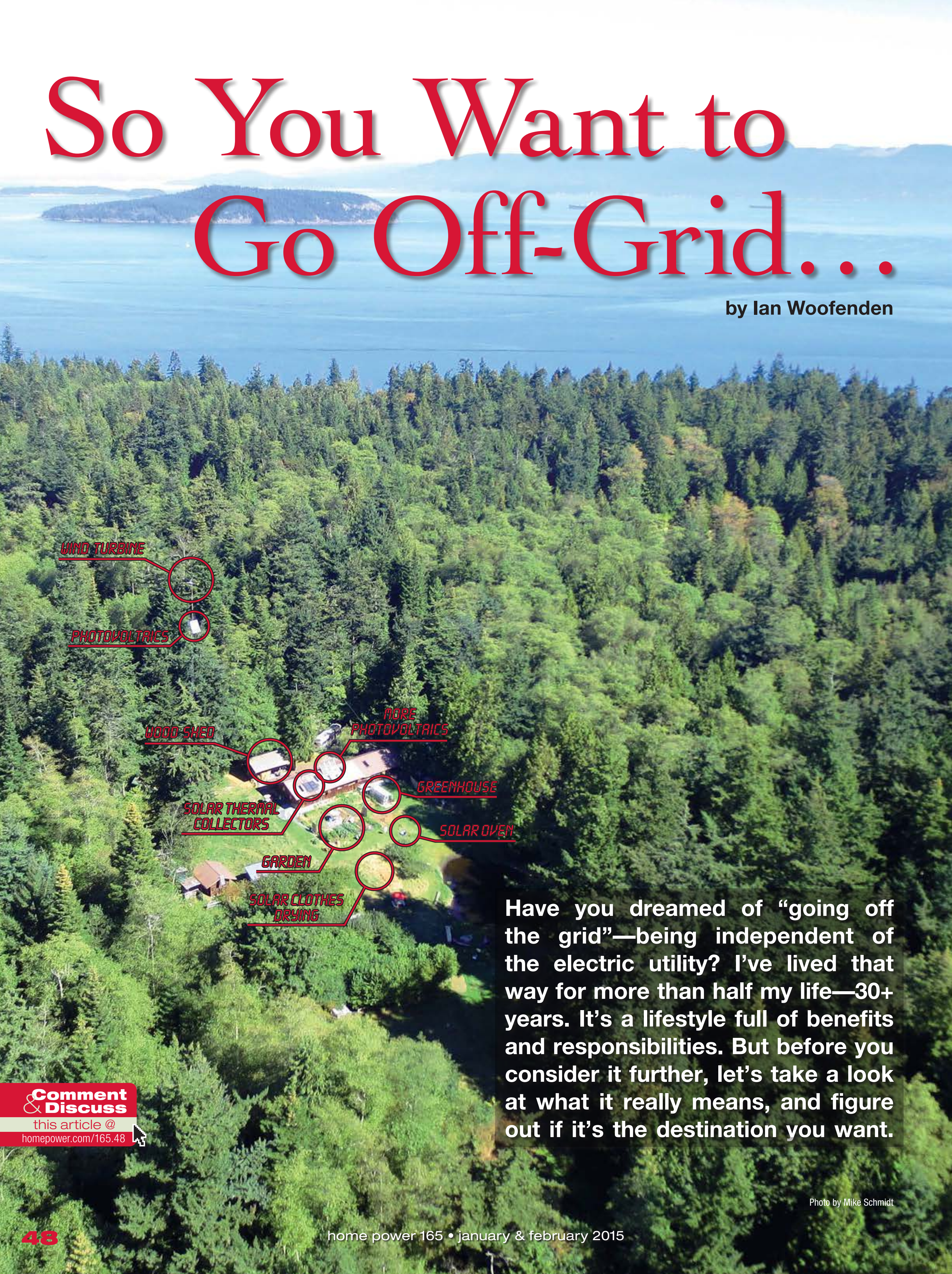
Here's an example: In my utility's (PG&E) service area in the summer, off-peak electricity costs about $0.10 per kWh and peak electricity costs about $0.40 per kWh. If I fully recharge an 80-mile EV like the Nissan Leaf at night, it will cost about $2.40. If I recharged it during the day, I'd pay about $9.60. The point is that you save money on the electric fuel itself by charging at night. On top of that, if my PV system is producing surplus energy during peak hours, I am selling that energy back to the utility at the $0.40 rate—instead of spending that valuable electricity to recharge my car.

But even without TOU metering, owning an EV and recharging it with a grid-tied PV system can make economic sense, and it doesn't really matter which comes first—the system or the car. You can put the PV system in now, and be prepared for next year's EV models to arrive, or start enjoying your EV's fuel savings now, and install a PV system as the next step.

This article was adapted from articles that appeared on PlugInCars.com. Thanks to August Goers at Luminalt for help with this article.

So You Want to Go Off-Grid…

by Ian Woofenden



Have you dreamed of "going off the grid"—being independent of the electric utility? I've lived that way for more than half my life—30+ years. It's a lifestyle full of benefits and responsibilities. But before you consider it further, let's take a look at what it really means, and figure out if it's the destination you want.

Photo by Mike Schmidt

Comment & Discuss this article @ homepower.com/165.48

Off-grid systems work independently—they are not connected to the electrical utility grid and, therefore, are not susceptible to brownouts or blackouts.

Why Off-Grid?

It's important to clarify the terminology. When I hear people say "off-grid," I often assume that they mean they want their home to be renewably powered with independent systems that make energy on-site. However, when I pry further—and ask if they actually want to cut the cord to the utility, the answer is usually no.

In the renewable energy (RE) industry—and in this article—when we say "off-grid," we mean that literally. The phrase refers to systems that have no connection with the utility grid, and must make all the electricity necessary for the home, business, or application.

Going off-grid is possible and practical in many cases, and the experience of thousands of early RE pioneers and recent off-gridders confirms that. But many people who toss out the phrase have a fairly romantic idea floating in their minds. They imagine having no utility bill, and energy and life being free and easy. The reality is that most utilities supply electricity at a modest cost, and if you take on their job, you have to play all the roles that the utility plays.

Identifying your motivation for going off-grid can clarify your goals and help you understand if the reality will please you. Your specific goals may affect whether going off-grid makes the most sense, and they also may affect the type of system you design and how you live with it. Common off-grid motivations include:

- Environmental concerns—a desire to use less energy and make as much as possible from renewable sources;
- Independence from the electrical utility for philosophical reasons or to eliminate vulnerability from utility outages
- Political/social values, such as taking responsibility for your energy impacts;
- Cost—depending on how far you are from the grid, it may make economic sense to stay disconnected.

Compared to battery-based systems, batteryless grid-tied systems have fewer overall components—usually just an inverter, a couple of disconnects, and a production meter.

Ian Woofenden (2)

On-Grid RE

I urge most folks to use the utility grid with their RE system. More than 40 U.S. states have some form of net metering available. This means that a large majority of U.S. utility customers can "bank" any surplus energy their PV system produces with their local utility, and use the credit to pay for future utility electricity usage.

Almost all U.S. homes have grid service available, and it's surprisingly reliable. Some locations may be less reliable, and it makes sense to find out how often your region has outages, and how long they typically last. If having completely uninterrupted electricity is important to you, a battery-based grid-tied system could be the best of both worlds—renewable electricity with utility outage protection. These systems provide electricity (usually for dedicated, not whole-house, loads) when the grid is down.

The most common grid-tied systems do not use batteries, and therefore do not have outage protection—their one disadvantage. Their advantages include lower cost, less complexity, lower maintenance, lower environmental impact, higher operational efficiency, and a longer overall system life, since there are no batteries to replace and fewer components.

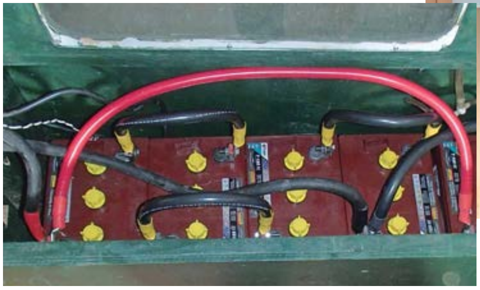
When Does Off-Grid Make Sense?

Your motivations and goals are key in coming up with your own answer. It doesn't need to make sense to anyone else if you *want* to be off-grid. But it is important to be realistic about what can be done and what it will cost—both in dollars, and in your time and attention. Additionally, there are some situations that make off-grid living either the only possible option or the most appropriate.

If you have property miles from the grid, or in a location that has no grid, your only affordable option may be to set up an independent system. If extending the utility grid to your property is possible, find out how much it will cost, and what the ongoing cost will be. Then you can make a sensible comparison to base your decision on. While $20,000 in line-extension costs may seem high, if you are looking to power a large home that has many loads, spending that money may be the best option. Be realistic about the burden (financial and otherwise) of living off-grid! On the other end of the scale, if it's going to cost you a quarter of a million dollars to extend the grid, an off-grid system may be very economical and sensible. (See "Methods" in this issue for more on the economics.)

Shawn Schreiner

Off-grid systems are often sized to meet a home's daily energy demands during the season with the fewest sun-hours.



With additional components like charge controllers, metering, DC breakers, batteries, and backup generators, they are more complex than batteryless systems.

Ian Woofenden (2)

How far your site is from the grid affects the cost of bringing in utility power—the farther away, the greater the economic viability of an off-grid RE system. But living where you want may make those costs worth it in the long run.

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There are situations where utility policies make connection costly or difficult. While many utilities encourage RE systems, others seem to throw up roadblocks to easy interconnection. Some utilities have high monthly base charges. Others require expensive equipment that is not necessary to safe interconnection. And others have burdensome paperwork and/or insurance requirements. Talking with your local utility, installers, and other RE users will help you understand the full cost and difficulty. Then you can make a sensible decision.

web extras

For more details about the differences between on- and off-grid systems, see **homepower.com/PV-Basics.**

"Before You Go Off Grid" by Allan Sindelar • **homepower.com/137.100**

"PV Systems Simplified" by Justine Sanchez & Ian Woofenden • **homepower.com/144.70**

Off-Grid System Design

The first major task in off-grid system design is load analysis. Without accurate measurements or estimates of energy use, it's impossible to design a system that will satisfy the need in the most economical way. Electricity consumption is measured in kilowatt-hours (kWh), and an accurate daily or monthly number is needed to start your system design.

If you currently live on-grid, you can start with your utility bill, which tells you how many kWh were used during the last billing period, and often summarizes the last year or more. Even better would be to have a year's worth of bills—which should be available from your utility. This will give you a baseline for your current energy lifestyle. Then you need to estimate how much energy your off-grid lifestyle will use. To be most cost-effective, you need to identify energy-efficiency and conservation measures you can implement, and you'll likely need to shift some loads from electricity to other energy sources.

It's fairly easy to reduce the energy load in a typical North American home by 15% to 20% using common energy-efficiency measures. More radical efficiency work can reduce the load up to 50% or more. On-grid, reducing your energy demand not only saves you money, but also reduces demand for energy created by nonrenewable sources. Off-grid, this strategy is especially profitable, since every kWh comes at a cost in generating capacity, battery bank size, and the need for a backup generator.

Most off-grid systems will need to find non-electric ways to provide for:

- Space heating
- Water heating
- Other significant heating loads, often including clothes dryer and range

Ben Root

While the low cost of PV modules has made the economic viability of solar water heating (SWH) systems questionable for on-grid applications, in an off-grid situation, SWH may be the best renewable option.

Options include passive solar design; solar hot water; solar cooking; wood heat and cooking; and propane. Larger RE systems on homes that include ultra-efficient appliances (such as minisplit heat pumps) may be able to handle some of these loads. But these will come at a high cost in RE generating capacity, depending on the need and the resource.

Courtesy Tulikivi

Space heating with electricity is usually prohibitively expensive with off-grid PV systems. Diverting heating loads to other resources—such as passive solar, solar hydronic, propane, wood, or a combination—is usually a necessity.

In the author's off-grid kitchen, a wood cookstove shares space with a propane range. The former can be used for some or all of the cooking in the winter, when the cookstove serves as the primary source for space and water heating.

Ian Woofenden (2)

Load-shifting to propane for space or water heating, or to fuel a backup generator means relying on another "grid"—the petroleum industry—and recurring bills.

web extras

For more on load analysis, see "Analyzing Your Electrical Loads" by Ian Woofenden • **homepower.com/156.104**

"Off-Grid Appliances" by Ian Woofenden • **homepower.com/140.106**

web extras

For more on system design, see “Designing a Stand-Alone PV System” by Khanti Munro • **homepower.com/136.78**

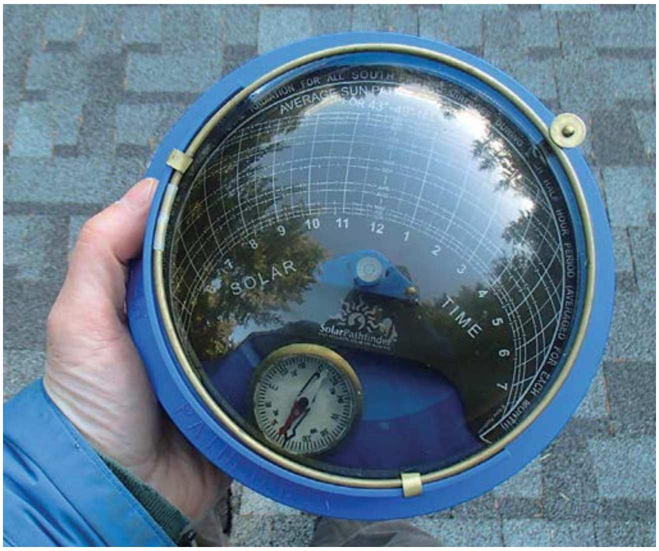
“Getting Started with Renewable Energy” by Ian Woofenden with Chris LaForge • **homepower.com/120.44**

The second step in off-grid system design is resource assessment. How much sun, wind, and/or falling water do you have?

Most off-grid properties rely on solar electricity, since sunshine is the most common resource. How much you have—measured in peak sun-hours—and when you get it is crucial to successful system design. Using measured data to find out your regional resource, and then a shade-analysis tool, such as the Solar Pathfinder, will give you a good idea of what a solar-electric system will do for you.

Left: Wind energy is a difficult resource to verify. Measuring your wind resource with an anemometer over time is a smart first step.

Below: A solar siting tool like the Solar Pathfinder helps determine shading at the potential PV array site.



Ian Woofenden (2)

Shawn Schreiner

Despite their drawbacks (noisy, dirty, expensive, and high-maintenance), generators are used in most off-grid systems for cloudy season backup power and battery equalization. Installing a PV system that’s large enough to meet wintertime demands without a generator usually means excess (wasted) generating capacity in the summer months.

Wind resource assessment is more complicated, as are wind-electric systems in general. Your goal is to measure or predict the *average* wind speed at your proposed wind turbine location and height. With this hard-to-get information, you can make an accurate prediction of how many kWh your chosen wind turbine could produce in a month or year.

Hydro resource assessment is fairly straightforward, and very specific to your stream. Measuring the “head” (vertical drop) and flow allows you to calculate the power and energy potential. If you have a decent hydro resource, it may be all you need.

System design also includes battery bank and backup generator sizing. Both are influenced by your loads—in the amount of energy they use and when they’re needed. RE capacity, battery bank, and generator sizing need to take into account your weak season. Solar-only systems have a season of fewer sun-hours (usually, during the winter), and this needs to be planned for. Hybrid (two or more sources) systems may find a balance that reduces the need for a larger battery bank and backup generator.

web extras

“Choosing the Best Batteries” by Chris LaForge • **homepower.com/127.80**

For more on generator selection and sizing, see “Engine Generator Basics” by Allan Sindelar • **homepower.com/131.96**

“Sizing a Generator for Your RE System” by Jim Goodnight • **homepower.com/138.88**

On-Grid Sojourn

After more than three decades of off-grid living, I had the opportunity to live on-grid for a time, caretaking a client's estate. I learned some lessons that may be useful to readers—both on-grid and off.

My off-grid reality and psychology on my family's homestead included:

- Limited energy
- Limited funds
- Generator dependence and/or avoidance
- Prohibited or discouraged loads

This led to a lifestyle of serious energy awareness, and included load shifting—wood for space heating and propane for the generator, as well as for some cooking and water heating. It meant daily observation of energy conditions, and adjusting energy use accordingly. At my off-grid homestead, laundry gets done when it's sunny or windy, or when we're willing to fire up "the noise"—my name for the propane generator.

Caretaking this grid-tied estate gave a dedicated off-gridder a firsthand education about on-grid energy-use habits and assumptions.

Fat & Sassy On-Grid

The caretaker cabin/guest house was originally the water tower house for the estate, built in 1947. The retrofit rebuilt it from the ground up. I learned a lot by first overseeing the transformation and then living in the cabin. Key lessons included:

Space heating. I missed my simple wood heater, including the possibility of getting *really* warm, and the ability to cook and heat water with wood. I also missed being able to easily dry and warm shoes and other clothing. The modern wood heater in the cabin was fussy and didn't hold a fire well. On the upside, the indoor/outdoor woodbox was an amazing innovation that made wood heat cleaner and more convenient than it's ever been on my homestead. I'm already planning this upgrade at my off-grid home.

The cabin has a minisplit heat pump, the most efficient and cost-effective conventional (but renewable, if it's powered by RE-made electricity) way to heat and cool a home. Living with it was convenient and effective. The home had no clothes dryer, and the indoor wooden drying rack and outdoor lines felt like my off-grid lifestyle.

An electric hot-air popcorn popper may draw a lot of power, but it's not used for very long, so its overall energy use is low—about 0.05 kWh per batch, according to the author's watt-hour meter.

Ian Woofenden (2)

Water heating. The main house has 35 kW of PV modules, a solar pool heating system, and a solar domestic water heater. These systems were installed per the owner's "get fossil fuels off my property" request, but the cabin's less-than-perfect solar access led me to recommend a conventional electric tank water heater be installed there. After measuring the water heater's energy use, I regretted not specifying a solar water heating system. For the nine months that I measured, the cabin's total electricity usage was an average of 17.6 kWh per day, and 9.7 kWh of that was the conventional tank water heater!

Appliance choices. The cabin uses almost all LED lighting, except for tube fluorescents in two closets. The results were encouraging—quality, efficient lighting, without too much design head-scratching or oddball product searching.

The cabin's other appliances performed well; none were a major energy draw. I rarely used the dishwasher—my personal preference.

On-Grid Loads? My off-grid perspective gave me some assumptions about what were and were not "big" loads, and I learned some lessons. On the homestead, I'd always used a non-electric popcorn popper on the wood or propane stove. The on-grid cabin had an electric blower-style popcorn popper. While it's not an insignificant instantaneous draw, it turns out that a batch of popcorn only uses 50 to 60 watt-hours. Learning this on-grid, I now indulge this energy usage back at my off-grid homestead at times. Similarly, the new and sophisticated Blendtec blender seemed like it would be a big load off-grid, but making a green smoothie in it is very similar in energy use to making a batch of popcorn. And even using an electric tea kettle is not prohibitive—only 60 to 70 watt-hours were used to heat a half-full pot.

continued on page 54

continued from page 53

The big on-grid loads I used in the cabin that are out of the question at my off-grid homestead are:

- Minisplit heat pump for space heating
- Tank water heater
- Electric range/oven
- Bathroom resistance space heater

In addition, I pay much more attention to phantom loads and general conservation—that is, I turn things off when they're not in use—while living off-grid.

Lessons

My primary take-homes from my time on-grid were:

- Energy awareness (and before that, literacy) is a key step. Most folks on-grid would not be aware of or analyze their energy footprint.
- Energy efficiency requires more motivation when you're on-grid.
- Measuring energy usage brings some surprises about what can actually be done off-grid.
- Some loads are indeed off-grid deal-breakers.
- Experiencing my first utility outage in 30 years was a new experience. I was able to charge my phone and laptop with the main house's battery backup system. My off-grid experience prepared me well for using wood for heating and cooking, and with patience for a variable energy supply.

What can you learn from my unusual throwback to being on-grid? Don't take your energy use for granted. Do the measurements and analysis. Try to imagine how you would need to live off-grid, and apply the lessons learned to your current energy lifestyle, whatever it might be. Consider how conventional energy is produced and the environmental impacts of your energy decisions. I'm happy to be back making and managing my own home energy, but also grateful for the perspective of a time connected to the utility.

A firewood portal makes heating with wood more accessible and minimizes the mess, but the cabin also has an easier option for space heating—the minisplit heat pump (far right).

Batteries make off-grid living and backup power for on-grid systems possible. But they can be expensive and may require some regular maintenance. The pros and cons of having a battery-based system should be carefully considered.

Ian Woofenden (2)

Reality Check

On-grid RE system owners have a great deal. When their resource—sun, wind, or water—is available, they use it. When they make too much energy, the grid takes the surplus and gives credit. And when it's dark, calm, or the creek is dry, the utility is there to provide the needed energy. *Off*-grid system owners have to take all the responsibility of generating all of their energy, all of the time.

The most challenging part of off-grid living is dealing with the variable resource. Raising a bunch of kids off-grid taught me a lot of lessons. One is that folks usually assume that electricity will be constant and abundant. This is part of our culture, and off-grid folks are not immune, since they interact with the on-grid culture on a regular basis. While there are many times when RE is very abundant—most every sunny day and whenever there's a windstorm, for example—there are other times when it's scarce. Surfing this wave of abundance and scarcity can be satisfying to some of us, but it's challenging to others.

Systems can easily be designed to overcome the variation, and to allow use of any load at any time. But this will come at the increased expense of needing more RE generation capacity, a larger energy storage system, and a larger backup generator. This also means a less efficient and less environmentally friendly system.

Your solar-electric array will give you 30 to 50 years of trouble-free service. Meanwhile, your battery bank—even if well cared-for—will need to be replaced multiple times. And if you don't treat it well, you may learn a hard lesson of having to replace this expensive component in just a few years. Some RE professionals suggest that new off-grid systems use a less costly battery bank initially—since there's a learning curve with battery care and it's best not to risk ruining an expensive bank while you learn.

Typical battery maintenance includes adding water, cleaning, and checking connections. More difficult but even

more important is setting up a charging regimen to work well. Batteries last longest if they are regularly recharged fully. The worst thing you can do for your battery bank is to discharge it and leave it in that state for days. Ideally, your battery bank should be fully recharged every few days—one way (RE) or another (fuel-fired generator).

A few off-grid systems are blessed with year-round hydro, or with a balance of resources (sun/wind and sun/hydro are common) that eliminate or radically reduce the need for a backup generator. And there are also users willing to reduce their usage when resources are not available, limiting the need for backup. But for most off-grid systems, a fuel-fired generator is a crucial part of the system. It's also one of the weaker parts—a loud, dirty, inefficient, and costly way to make electricity. Best system design includes a modest backup generator that is used as little as possible.

Getting it Done

If you're determined to live off-grid, you need to figure out how to make it happen. A crucial decision is whether you will leave the system design and installation to the pros or do it yourself.

If DIY sounds like fun, you'll need to get an education. *Home Power* articles, and classes, workshops, and more advanced training may be part of your learning process. And in the end, you'll need to buy your equipment from someone. I recommend *not* buying from the cheapest online source, but finding a source (preferably local) that can also give you advice and support as you design and install your system. This will be worth the somewhat higher cost, since one or two bad buying or design choices can negate a "bargain" purchase.

Most modern RE systems are installed by experienced contractors. But bear in mind that nearly all solar contractors spend their time selling and installing batteryless on-grid systems. And many of them have *zero* experience with battery-based systems—avoid these companies, even if they are professional and want to help. Find an RE contractor with a history of designing and installing off-grid systems, or at least one who has experience with battery-based systems.

Take a hard look at your situation before you jump into the off-grid lifestyle. You may find that a grid-tied system will serve your motivations and goals best—at a lower cost and lower environmental impact. If you choose to be off-grid, get realistic, get educated, and get good help. And then enjoy your independence with renewable electricity!

web extras

"DIY or Pro?" by Joe Schwartz, Ian Woofenden & Justine Sanchez • **homepower.com/145.48**

Check out our many off-grid system profiles at **homepower.com/solar-electricity/project-profiles.**

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The *International Fire Code* & PV Systems

by Ryan Mayfield

In *HP164*, "Code Corner" discussed Section 690.12—new *National Electrical Code (NEC)* requirements for controlling PV conductors on or in buildings. This time we tackle a complementary section—605.11—in the 2012 *International Fire Code (IFC)*. The 2012 *IFC* was adopted by a number of jurisdictions and has been getting a lot of attention in the PV industry, since it addresses labeling requirements, equipment locations, and clearances around rooftop PV equipment. Detached, nonhabitable Group U structures (such as agricultural buildings, barns, carports, garages, parking structures, and pergolas) are exempt from 605.11 requirements.

Examining the overall intent of the *IFC* can help you understand the requirements framework. The intent, according to Article [A] 101.3, is "to establish the minimum requirements consistent with nationally recognized good practice for providing a reasonable level of life safety and property protection from the hazards of fire, explosion or dangerous conditions in new and existing buildings, structures and premises, and to provide safety to firefighters and emergency responders during emergency operations." Careful consideration needs to be made for the layout of rooftop systems in advance of the permitting process, since rearranging modules after the design is completed can be a difficult and costly endeavor.

All raceways containing DC conductors from the PV system must be installed in specific locations and labeled with specific language as defined by the *IFC* and *NEC*.

Courtesy Renewable Energy Associates

Section 605.11.1 governs marking electrical assemblies containing DC conductors in both interior and exterior locations to help emergency personnel quickly identify (and shut down) energized sources, which could pose a shock hazard. These requirements mirror the requirements set in Section 690.31(G) of the 2014 *NEC*. All raceways, enclosures, junction boxes, cable assemblies, combiners, and disconnects need to be clearly labeled to indicate the presence of PV conductors. The labels shall have "WARNING: PHOTOVOLTAIC POWER SOURCE" in all-white, capital letters, a minimum of 3/8 inch tall, on a red background. These labels must be reflective and weather-resistant.

IFC mandates the marking locations on all interior and exterior raceways, enclosures, and cable assemblies. This labeling has the added benefit of helping ensure the conductors won't be confused with those from a different electrical system, like an AC circuit that could be used to run a new load. This section's labeling must be applied:

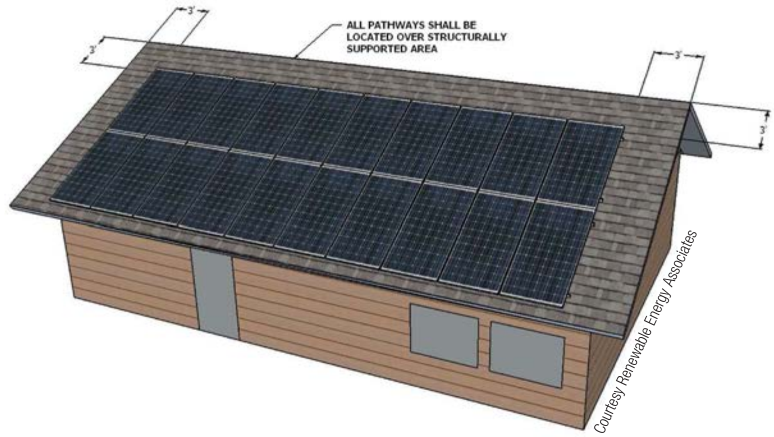
- Every 10 feet
- Within 1 foot of turns or bends
- Within 1 foot of penetrations through roofs/ceilings, walls, or other barriers

Section 605.11.2 specifies the locations for DC conductors—to minimize trip hazards for firefighters and not obstruct potential areas for ventilation access. The *IFC* accomplishes this by requiring PV circuit raceways be run as close as possible to the roof's ridge, hip, or valley. Raceway transitions from a hip or valley should take the shortest/most direct path to an exterior wall. If combiners or junction boxes are used for multiple subarrays, they should be installed and connected in a manner that minimizes raceways on any pathways and that keeps the raceways as short as possible. As with the *NEC*, metallic conduit or raceways are required for DC circuits located inside buildings.

The next section, 605.11.3 Access and Pathways, can be the most challenging section of 605.11 to meet, although local AHJs may allow exceptions. Section 605.11.3.2.4 governs roof access for smoke ventilation, and is applicable to all rooftop installations, regardless of roof type. To meet this section's requirements, modules must be installed at least 3 feet below a roof's ridge. Since this is not a pathway requirement, the space doesn't have to be clear of obstructions.


Courtesy Quick Mount PV

This rooftop installation minimizes trip hazards by routing the raceway adjacent to the array and leaving the required space near the roof for ventilation access.



Courtesy Renewable Energy Associates

Gable roofs require two 3-foot-wide pathways from eave to ridge, as shown, in addition to 3 feet of space between the ridge and top of the array for smoke ventilation.

The array cannot block access to the roof for firefighters attempting to gain access from the ground. Available roof access points must be able to support a firefighter's load and not be located directly in front of windows and doors. For the pathway requirements, the *IFC* establishes rules for three specific roof layouts: hip, gable, and hip-and-valley. These rules apply to roof slopes greater than 2:12 pitch and require the pathways to be located over structurally supported areas that can support the live load of a firefighter.

For hip roof layouts, 605.11.3.2.1 requires a single 3-foot-wide, clear pathway from ridge to eave on each slope where modules are located. Buildings with a single roof ridge (aka gable) are covered under 605.11.3.2.2, which requires two 3-foot-wide, clear pathways from ridge to eave on each slope where modules are installed. The exact location for each pathway is not defined; typically, the most convenient location will be on outer edges of the roof as long as they are structurally supported.

Pathway requirements for buildings with hips and valleys are detailed in 605.11.3.2.3. These complex roof shapes can make meeting the *Code* difficult. They must have at least one 3-foot-wide, clear pathway from ridge to eave on the slope that has modules, regardless of what is on the other side of the roof. If there are modules on both sides of the hip or valley, then a minimum 18-inch pathway needs to be provided on both sides of the hip or valley (to create a 3-foot-wide pathway). If the other side of the hip or valley is without modules, the PV array can go all the way to the hip or valley.

Premade *IFC*/*NEC* labels can be found at:

Hellermann Tyton • hellermanntyton.us

PV Labels • pvlabels.com

Specialty Solar Supply • specialtysolarsupply.com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The StarFlower

by Kathleen Jarschke-Schultze

Last summer, I was very excited to get a call from an old friend of mine, Sam Erwin. Sam had invented what I considered to be the most efficient solar cooker I have ever used. Sure enough, he was calling me about his new solar cooker, the StarFlower (see solar-chef.com).

First: The Solar Chef

I first read about Sam's early solar oven, the Solar Chef, in Joe Radabaugh's book, *Heaven's Flame*. I saw my first Solar Chef and met Sam at a Solar Energy Expo and Rally in Willits, California, in August 1994. He had transported the very large "restaurant-sized" Solar Chef from Colorado, where he and his family had used it for 18 years. He was roasting whole ears of corn, husks on, and handing them out to fair-goers to showcase solar cooking. That year, Sam sold every unit he brought to the fair. And that corn was yummy!

The Solar Chef arose from a homemade solar water heater gone awry. It wasn't working very well as a water heater, so Sam removed it from his roof, stuffed an uncooked chicken inside a coffee can, and put that in the unit. It cooked surprisingly well. That was when Sam began fine-tuning the now-patented solar cooker design.

The original Solar Chef is a handsome unit. The center cooking enclosure is covered with a faceted glass cover that is the focus of many mirrors cut and mounted just so. The outside is plywood, painted a neutral brown and cream. The aluminum frame and wheels are what make the Solar Chef so easy to use. The one we bought had a painted wooden cover that slips underneath the cooker to provide a smooth surface for the wheels.

Chef Deux

In 1997, Sam, who had been testing and fine-tuning his cooker, sent me a newly designed Solar Chef. The cooking chamber on this model is covered by a molded, clear plastic dome instead of glass, and has reflectors made of polished metal. They radiate from the cooking chamber like the petals of a large metallic flower. On the back of each "petal" is a bow of metal with an adjustment screw positioned two-thirds of the way up the bow. Turning a knurled screw on the bow allows you to change the curve of the collectors according to what you are cooking. If you are cooking in a pot, you want the light to be very focused on the pot. If you are baking bread, you would want the light/heat more diffused to eliminate hot spots. The Solar Chef finished a 15-pound turkey in 15 minutes less time than called for on my cooking chart. It has quickly become my favorite of all the solar cookers I have used or tested over the years.

We still have and use our Solar Chef. It has become a venerable friend, sitting outside our back door, where it can get full sun. Usually, the recipe rule for solar cookers is that it will take roughly twice as long in a solar cooker as in a conventional oven. But the Solar Chef cooks in real time. This doesn't mean "set it and forget it" like with an electric slow cooker—it means set your time, and check the oven when the alarm sounds.

The StarFlower

That's why I was delighted to hear from Sam this past summer. I thought he had retired—but no, he had been working on and improving his cooker. He offered to let me test the new StarFlower cooker. I jumped at the chance.

My brother-in-law happened to be visiting family a couple of hours from where Sam now lives. He was able to visit Sam, get instructions for assembling the unit, and pick up the StarFlower parts, which were in several boxes.

Now, I love assembly—you know, putting things together according to a plan. Just me, the instruction sheet, and a bunch of parts waiting to become a whole. It's so Zen. Being familiar with the various incarnations of the Solar Chef gave me a foreknowledge of design. This cooker also has petal-shaped metallic reflectors mounted around a central cooking chamber. The control for elevation adjustment is the same. The cooking chamber is covered by a molded, clear plastic dome. There is also an option of buying a dome that contains a small solar-powered fan for convective cooking.

The cooking chamber sits on a turntable. The turntable is attached to a base that can be fit with casters or legs. Placed like large leaves on each side of the turntable are two small

shelves that turn with the cooking chamber. These are handy places for resting oven mitts and seasonings, and setting down pot lids.

Sitting atop the reflectors are the ”power petals”—what give the cooking chamber temperature some extra oomph. Shaped like small lily pads, they mount to the spines that hold the larger metal reflectors in place.

Smoke from local wildfires hampered the testing, since I needed ample sunlight to test the StarFlower. But when I did, it performed like a champ. I placed it on the solar cooking platform I made from the bottom of a defunct redwood hot tub. I chose to use the table leg base configuration so the cooker would not roll off the platform.

I used my Polder digital cooking thermometer, which has a plug-in temperature probe on a wire that I was able to place in the cooker next to the cooking vessels. The StarFlower baked some carrot bread in about 35 minutes, at 325°F. For my next dish, a large casserole, the oven temperature rose to 350°F in about 30 minutes. There was a lot of liquid in the casserole and that has a tendency to slow the temperature's climb. But once the dish reached 350°F, maintaining the temperature was easy by turning the cooker to keep the sun focused on the cooking chamber.

One bright sunny day, I put a whole winter squash in the oven with the temperature probe next to it. The first time I checked the temperature and refocused the cooker, the thermometer readout said 386°F. I was pretty excited. I refocused the cooker and watched the temperature climb. When it got to 400°F, my digital readout blipped—apparently, it had reached its readout limit. I quickly located one of my analog oven thermometers and put it next to the squash. It read 435°F! It didn't take long for that squash to be done.

The StarFlower is being beta-tested. Production on this model has not yet started, but interested parties can contact Sam Erwin at P.O. Box 151, Tracyton, WA 98393; (303) 373-1027.

Kathleen Jarschke-Schultze

I have cooked pots of beans, rice, breads, casseroles, squash, and fruit cobblers in the StarFlower. It cooks in real "recipe" time—or less. Everything I've cooked has been delicious.

Design Savvy

The StarFlower makes solar cooking almost effortless. It is so easy to turn and elevate to focus the sun onto the cooking chamber. The chamber itself is stationary, and keeps the pots and food level as you refocus the unit. The small side table and leaves turn with the unit and are so practical for storing cooking implements. The design is well-thought-out on a practical level.

I didn't think it was possible, but now another favorite solar cooker has stolen my heart, and enriched my solar cooking experience.


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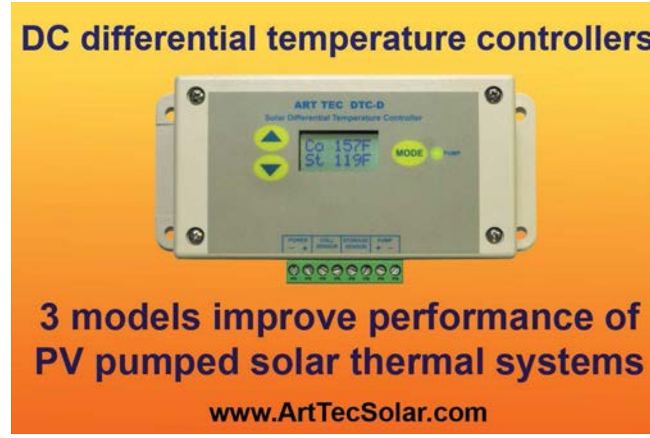
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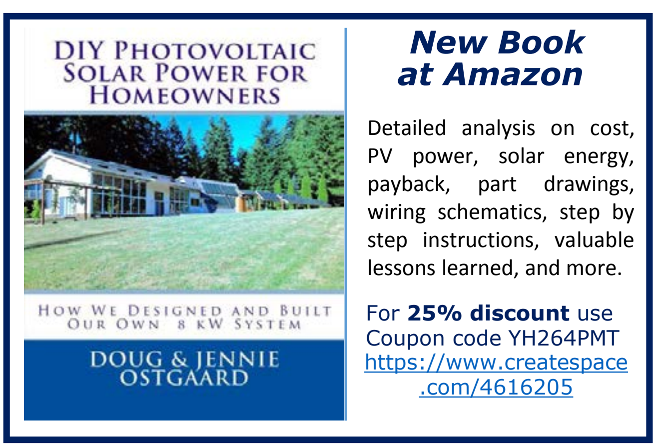
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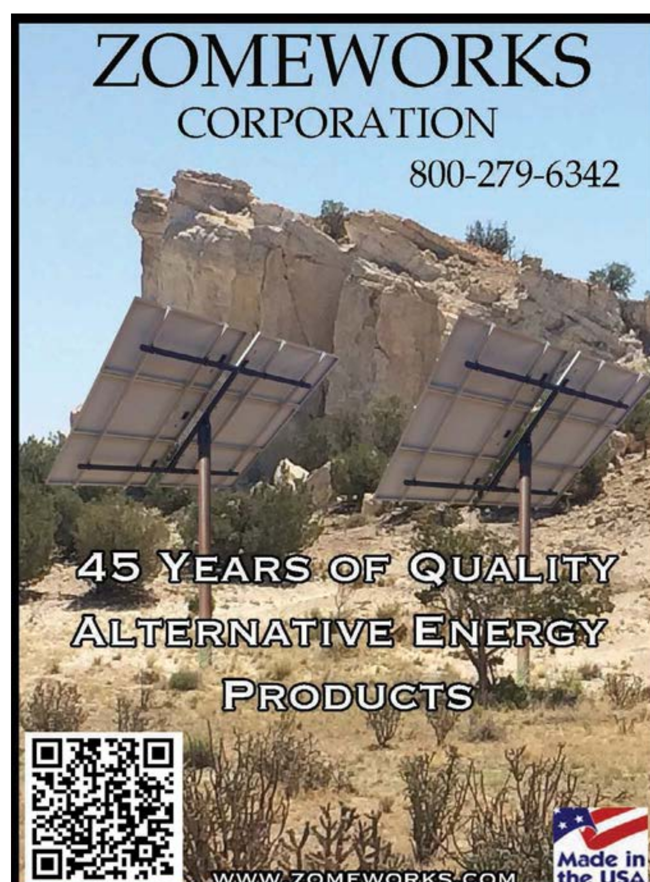
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Clean to Be Greener

Dirt and dust buildup on the modules can reduce your PV array's energy output, so implementing a regular cleaning protocol can be important.

The newly updated PV energy calculator PVWatts assumes that module soiling can cause a 2% reduction in array energy output—making losses over the array's lifetime add up. In some locations that are particularly dusty and have little rainfall, losses in dusty or heavily industrial areas could easily be 25% to 30% of the array's potential output. On the other hand, if you have no local industrial polluters, but have regular rainfall—and your PV modules are at a steep-enough angle to allow rain to wash down the glass—the effects of soiling on the system's output could be minimal, and not worth worrying about.

Determining if it is worthwhile to spend time cleaning a PV array is a value judgment that calls for more information than just the local soiling and rainfall conditions. For example, those additional kWh may not be worth trying to capture if the array is on a roof that is difficult or dangerous to access, or if getting running water to the roof is troublesome. A ground-mounted array is likely to be easy to clean, and there's little reason not to do it at least seasonally.

Commercial window-washing has brought telescopic soft-fiber brushes to the market that are appropriate for washing PV modules. Some can even be coupled to a hose, bringing water right to the bristles. (Shop for "boat-cleaning" brushes—about $35.)

Some PV array washing companies use purified water to avoid hard-water stains and spots, but usually it's sufficient to scrub—or even just rinse—them with tap water. However, water alone might not remove grime. In that case, use a mild detergent that won't damage aluminum—usually something suited for washing your car will be acceptable. Follow the suds with a water-only rinse.

For time or safety reasons, you may consider hiring out the array-washing task. In metropolitan areas, there are businesses that specialize in cleaning arrays. Check with local installers—they will likely know of cleaning companies or may even be able to offer you a maintenance contract that includes periodic cleaning.

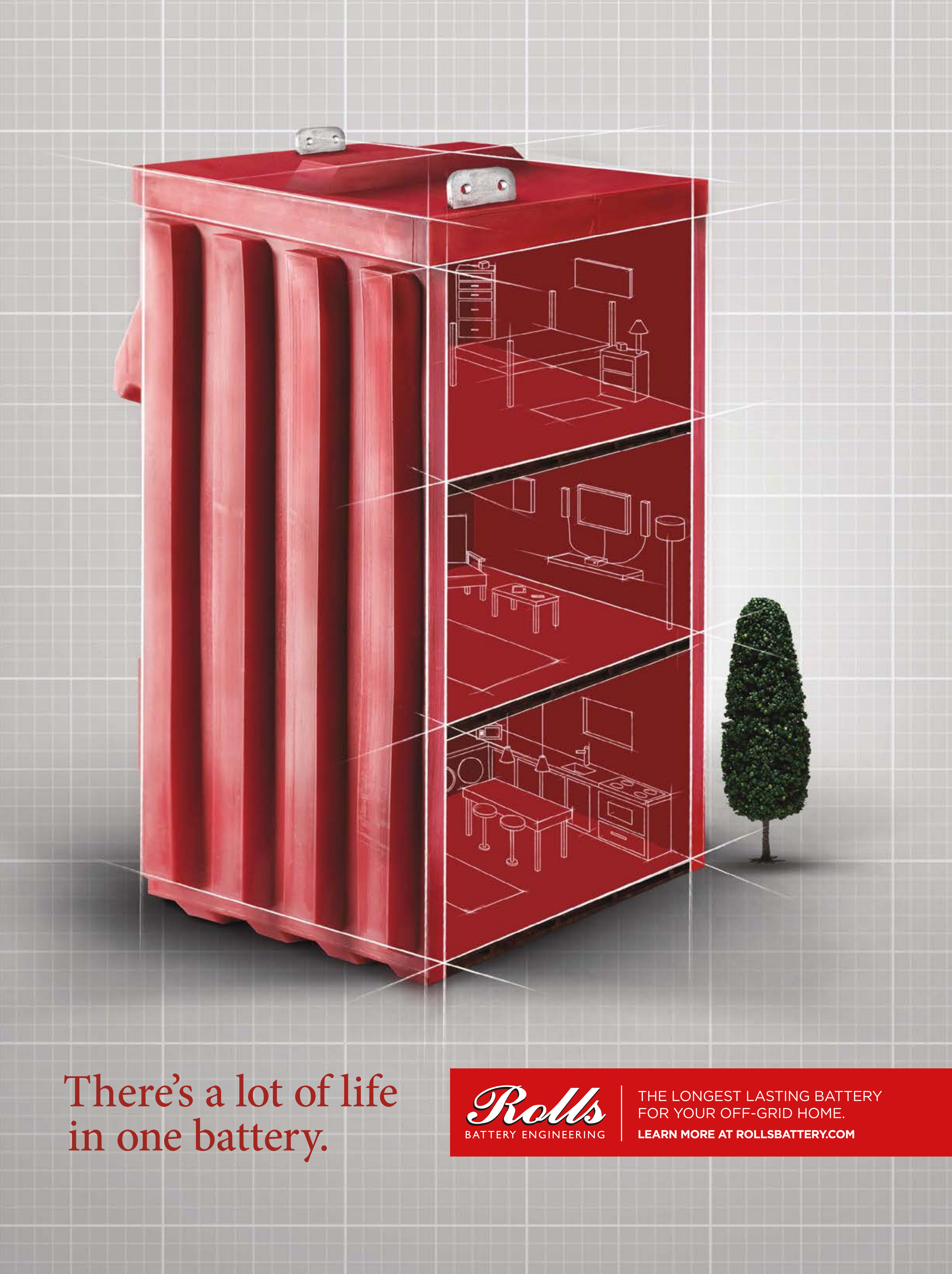
Not everyone agrees that it makes economic sense to regularly wash a home-scale PV array. Differences in regional circumstances aside, a study published by the University of California at San Diego showed that California arrays that had not been rained on or washed during 145 days of summer drought conditions lost only 7.4% of their efficiency, which equated to about $20 worth of energy in a 5 kW array. It would likely be impossible to hire someone to do the job for that small amount of money.

Automated washing systems are becoming available for home-scale rooftop PV systems. While I cannot vouch for their effectiveness, one washing system can mimic a rainstorm by spraying from sprinkler heads permanently installed between the rows of modules. For a periodic deeper washing, they can also spray a detergent mixture and then follow with rinse water. Another system under development uses a solar-powered robot, similar to a household robotic vacuum cleaner, that activates during rainstorms to scrub the array.

—Michael Welch

Cleaning the carport PV array at Googleplex in Mountain View, California.

Courtesy Avinash Kaushik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